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WELCOME

The magazine that feeds minds!

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"There's always a low background level of radiation"

Deadly radiation, page 24

Radiation is all around us all the time, and some of it is the ionising kind - the stuff that smashes into our DNA and damages it. But don't worry – it's rarely present in sufficient doses to do us any harm in our day-to-day lives. In fact, we've developed technologies that can harness damaging X-rays and other forms of ionising radiation for the good of humankind. In this issue of **How It Works**, we explore the deadly yet fascinating extreme end of the electromagnetic spectrum, home to invisible alpha, beta, gamma and neutron rays. Discover both natural and human-made sources of radiation, and how we can detect and protect ourselves from it. Enjoy the issue!

Ben Editor

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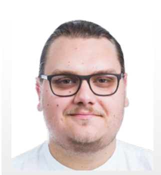
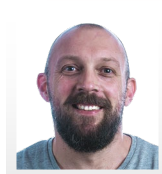
Meet the team...

Nikole
Production Editor
What lies in the vast space between stars? It's not empty like you might think. Explore the darkest parts of the galaxy on page 84.



Scott
Staff Writer
On page 50, discover how sunlight and car exhaust combine to create toxic smog that poisons cities around the world.

Baljeet
Research Editor
Is supersonic flight the future of travel? Meet the new craft aiming to get passengers around the world in less time on page 66.



Duncan
Senior Art Editor
The most extreme temperatures – both hot and cold – affect the elements in interesting ways. Learn more on page 32.

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Billionaires can buy almost anything. On page 72, check out the most extravagant home tech owned by the world's richest.

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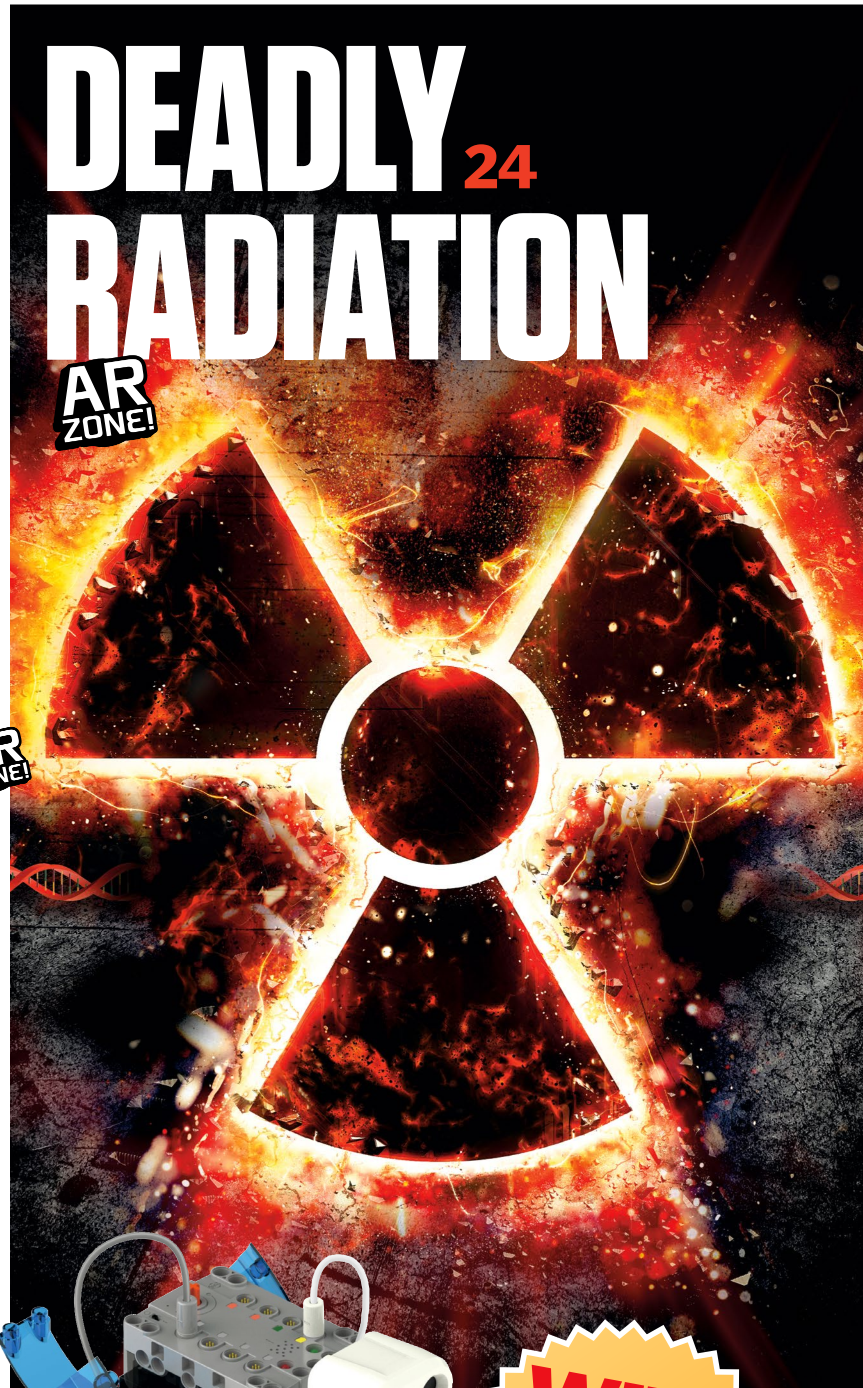

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MEET THIS ISSUE'S EXPERTS...


Lauren Eyles
Marine biologist and PADI dive master Lauren has been leading the fight against plastic pollution for over ten years. She's appeared on BBC *Coast*, *Springwatch* and other wildlife programmes.


Andy Extance
Andy is a freelance science writer based in Exeter, UK. He previously worked in early stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.


Dr Andrew May
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

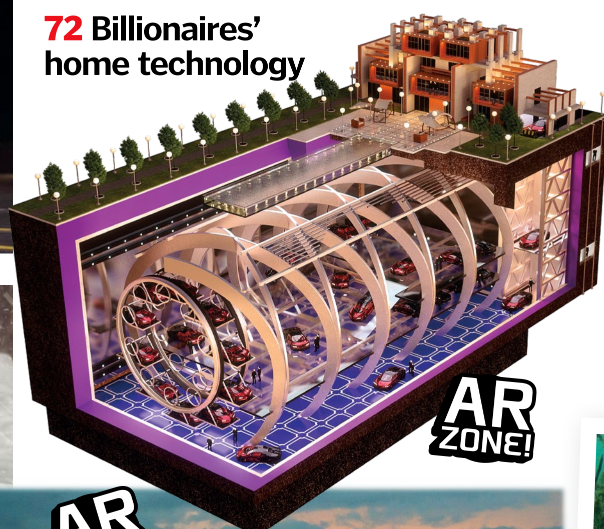

Laura Mears
Biomedical scientist Laura escaped the lab to write about science and is now also working towards her PhD in computational evolution.


Mark Smith
A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.


Jo Elphick
Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She is also the author of a number of true crime books.


Amy Grisdale
Volunteer animal worker Amy has an enormous breadth of experience on animal conservation projects. She specialises in writing about environmental topics.

REGULARS



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AR ZONE!

AR ZONE!

Scan the QR code with your device's camera or download a free QR code reader app. Many iPhone and Android devices include a QR reader

When you see the AR ZONE! logo at the top of a page, use your phone to scan the QR code, which looks like this

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HOW THE AUGMENTED REALITY WORKS

After being launched by the QR code, the app reads anything you point your device's camera at 30 times a second, searching for distinctive shapes we've trained it to recognise. When it sees a familiar picture, it overlays the augmented-reality 3D image we've previously uploaded on your screen.

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SCALLOP SIGHT

Did you know that scallops have eyes? Meet the bay scallop (*Argopecten irradians*), typically found in pocket populations along the Atlantic coast. These saltwater bivalves – molluscs with a hard shell and two internal valves – have a striking appearance. Rows of vibrantly blue eyes and teeth-like tentacles transform them into sci-fi monsters from the deep. Though they're a far cry from our complex optical organs, a scallop's eyes work in a similar way. Light enters the pupil and retinae, reaching a biological 'mirror' at the back of the eye where it's reflected to a cluster of nerve cells that trigger an action in the scallop, such as swimming away when a predator is near.

YELLOWSTONE'S HOT SPRING

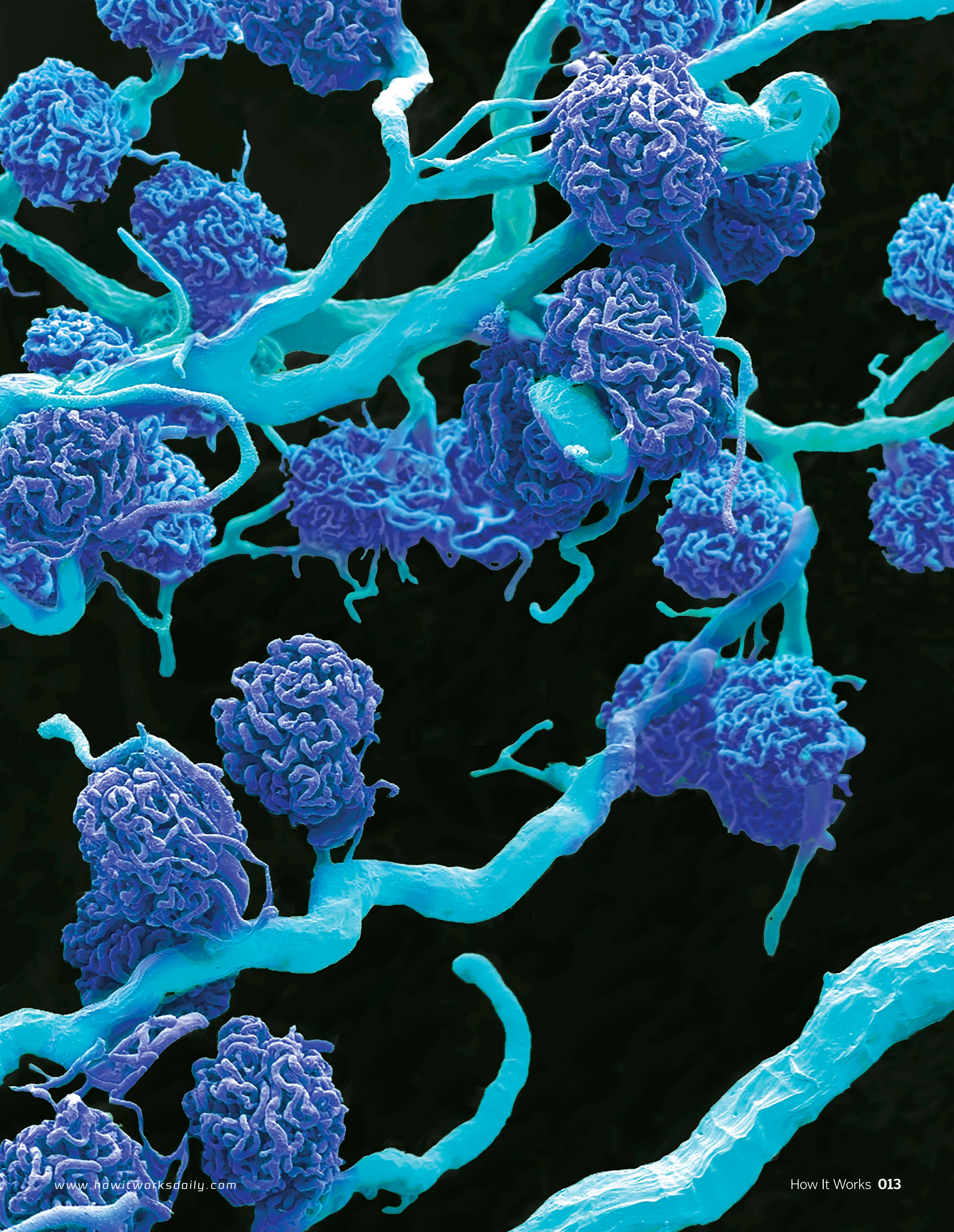
Located in America's Yellowstone National Park, the Grand Prismatic Spring is the third-largest spring in the world, spanning almost 113 metres in diameter. Thanks to a crack in the Earth's surface around 37 metres deep, hot subterranean waters can travel up to form this sweltering pool, which is around 87 degrees Celsius. At its border the ground has been coloured in bands of orange, yellow and green. These hues are the result of different heat-loving bacteria species, called thermophiles. As photosynthetic bacteria, these single-celled organisms use pigments called carotenoids to turn sunlight into energy in the same way that plants use green chlorophyll pigment. Carotenoids are seen in a range of colours in different species of bacteria. As the water fans out from the centre of the spring, the temperatures cool, allowing bacteria species with individual temperature tolerances to thrive and produce these varied colour bands.

A STAR IS BORN

The Small Magellanic Cloud is a dwarf galaxy orbiting the Milky Way from around 200,000 light years away. It spans around 7,000 light years across and can be seen in the Southern Hemisphere sky. Within this small galaxy is a star-forming nebula called NGC 602, shown in this image. The brilliant-blue stars at the centre of the image are freshly formed. They have blown apart the nebula to create wing-like pillars of cosmic dust. The dusty material that makes up these pillars will continue to feed the growing stars. This image was taken by the Hubble Space Telescope and will help to advance astronomers' knowledge of how stars form in galaxies beyond our own.

FILTRATION UNDER THE MICROSCOPE

This image looks like an ultraviolet bonsai tree, but it's actually the glomeruli of a kidney. This is a loop of capillaries that twists into a ball shape and is the site of ultrafiltration of blood. These structures in the kidneys are typically surrounded by a group of cells called the Bowman's capsule, which has been removed from this image. The function of each glomerulus bundle is to filter out waste products from the blood, which has been delivered by arteries called arterioles. That waste is then transported as a liquid to the bladder via a tube called the ureter and eventually evicted from the body in urine. This image was taken using a coloured scanning electron microscope (SEM) with the glomeruli cast in a polymer resin.



SPACE

Astronomers spot the fastest star in the galaxy

Words by **Rafi Letzter**

A rapidly twirling, ultramagnetic 500-year-old baby neutron star has been spotted zipping at never-before-seen speeds through the Milky Way. The flickering X-rays and radio waves of this giant baby, adorably named J1818.0-1607, would likely have first appeared in the sky when Nicolaus Copernicus, the Polish scientist who proposed that the Sun, and not Earth, was the centre of the universe, first looked up at the heavens.

If Copernicus had orbital X-ray telescopes or powerful radio receivers, he would have witnessed the birth of a magnetar: a super-rare, violent species of neutron star with extreme, twisted-up magnetic fields. A mere 500 years later – assuming astronomers got its age right – this screaming infant is still spinning faster than any known magnetar, at one revolution every 1.4 seconds. It may also be moving faster than any previously discovered neutron star of any variety.

Like all neutron stars, J1818.0-1607 would have emerged after the explosive death of a large star, known as a supernova, as the crushed remnant of its core. Neutron stars are tiny in astrophysical terms, typically just 12 miles in diameter. But as the densest known objects in the universe other than black holes – full of matter crushed to the point of atoms losing their structural integrity and mushing together to resemble the nucleus of a single giant atom – neutron stars can be as massive as full-size stars.

Only a minuscule fraction of neutron stars are magnetars. But that isn't the only unusual thing about J1818.0-1607. It's also a pulsar, a type of ultrafast, cosmic lighthouse that dims and brightens with each rotation. "Only five magnetars, including this one, have been recorded to also act like pulsars, constituting less than 0.2 per cent of the known neutron star population," said researchers.

To determine the age of the magnetar, the researchers tracked how it slowed over time and estimated the spin rate it was born with. From its starting rotational speed, it would have taken 500 years for the newborn magnetar to slow to its current rate. However, this age estimate is somewhat unreliable. Because the magnetar is so young, astronomers should be able to spot the remnant of the supernova that birthed it, and the researchers may have found it a 'relatively large' distance from the magnetar.

If the magnetar really is 500 years old and that supernova remnant really is the leftovers of the magnetar's birth, then it's been moving about 8 to 16 million miles per hour through the Milky Way for its entire lifetime, faster than any of the approximately 3,000 other known neutron stars. If, however, astronomers estimated the wrong age for the magnetar, or the researchers identified the wrong remnant, then this youngster may not be moving quite so fast.

But although this baby is a newborn in astronomical terms, there may be an even younger magnetar in the Milky Way, though perhaps a slower moving one. Researchers think they may have witnessed the actual birth of a magnetar in a distant galaxy last year, making that newfound magnetar no older than a human toddler.

Anglo-Saxon textiles became mineralised due to close proximity to a metal brooch

Museum of London Archaeology (MOLA)

HISTORY

Massive Anglo-Saxon cemetery and treasure trove unearthed

Words by **Harry Baker**

A massive Anglo-Saxon burial site has been uncovered in Northamptonshire in the UK. Nearby, archaeologists also discovered a 4,000-year-old Bronze Age burial site. The archaeologists uncovered a total of 154 Anglo-Saxon burials, dating back around 1,500 years, holding nearly 3,000 objects ranging from weapons to jewellery. A nearby Anglo-Saxon settlement also held 42 structures that were approximately 1,500 years old. The Anglo-Saxon period lasted for about 600 years, from about 410 to 1066 CE, when migrants settled in England, so the new discovery would have dated to the early part of that period.

Older finds at the site included 46 prehistoric burials and seven structures – three burial mounds called barrows and four buildings – dating back to the Bronze Age, which lasted from about 2300 to 800 BCE in Britain. The treasure trove of artefacts provides a snapshot of how these ancient people lived and died.

The site was only discovered when several companies began developing a new housing estate near the small village of Overstone. Archaeologists from the Museum of London Archaeology (MOLA) carried out the site excavation, which was funded by the housing companies that bought the land, Barratt and David Wilson Homes. "The Overstone site contains by far the biggest Anglo-Saxon cemetery ever found in Northamptonshire," said project manager Simon Markus, an archaeologist at MOLA. "It is rare to find both an Anglo-Saxon settlement and a cemetery in a single excavation."

The team unearthed approximately 150 brooches, 15 rings, 2,000 beads, 25 spears, 40 knives and 15 shields, as well as personal objects such as cosmetic kits and bone combs. Another noteworthy find was a patch of Anglo-Saxon textiles. Usually such ancient fabric disintegrates before archaeologists can get to it, but this scrap was mineralised and preserved by a nearby metal brooch. "The excavations will help us understand the way people lived in both the Anglo-Saxon period around 1,500 years ago, as well as the Bronze Age nearly 4,000 years ago," said Markus.

"The excavations will help us understand the way people lived"

An image shows a newly discovered magnetar that spins unbelievably quickly through the Milky Way

SPACE

Upward 'blue jet' lightning spotted from ISS

Words by **Nicoletta Lanese**

Scientists on the International Space Station (ISS) spotted a bright-blue lightning bolt shooting upwards from thunderclouds. Blue jets can be difficult to spot from the ground since the electrical discharges erupt from the tops of clouds. But from space scientists can peer down at this light show from above. On 26 February 2019, instruments aboard the ISS captured a blue jet shooting out of a thunderstorm cell near Nauru, a small island in the central Pacific.

The scientists first saw five intense flashes of blue light, each lasting about 10 microseconds. The blue jet then fanned out from the cloud in a narrow cone shape that stretched into the stratosphere, the atmospheric layer that extends from about 6 to 31 miles above the Earth's surface.

Blue jets seem to appear when the positively charged upper region of a cloud interacts with the negatively charged boundary between the cloud and the air above. The blue jet appears as a result of this 'electric breakdown', where the opposing charges swap places in the cloud and briefly equalise, releasing static electricity. However, the properties of blue jets and the altitude to which they extend above clouds are not well characterised, so this study adds to our understanding of the dramatic phenomenon.

Four of the flashes preceding the blue jet came with a small pulse of ultraviolet light (UV). These emissions have been identified as so-called 'ELVES', another phenomenon seen in the upper atmosphere. ELVES, an acronym that stands for Emissions of Light and Very Low Frequency Perturbations due to Electromagnetic Pulse Sources, are light emissions that appear as rapidly expanding rings in the ionosphere, a layer of charged particles that extends from roughly 35 miles to 620 miles above the planet's surface. ELVES occur when radio waves push electrons through the ionosphere, causing them to accelerate and collide with other charged particles, releasing energy as light.

"The scientists first saw five intense flashes"

The team observed the flashes, ELVES and blue jet using the European Space Agency's Atmosphere-Space Interactions Monitor (ASIM), a collection of optical cameras, photometers, X-ray detectors and gamma-ray detectors attached to a module on the space station.

"This paper is an impressive highlight of the many new phenomena ASIM is observing above thunderstorms," said Astrid Orr, physical sciences coordinator for human and robotic spaceflight with the European Space Agency, about the new research. Experts also suspect that upper-atmosphere phenomena, like blue jets, may affect the concentrations of greenhouse gases in the atmosphere, since the ozone layer sits within the stratosphere where they occur.

A new report published 20 January 2021 revealed blue jets, or ELVES, shooting from Earth's atmosphere


The mausoleum is located in the city of Luoyang, China

© Alamy

HISTORY

Tomb of murderous Chinese emperor identified

Words by **Owen Jarus**

While excavating a mausoleum in Luoyang, China, archaeologists discovered an artefact that may finally confirm that a mysterious tomb belongs to Emperor Liu Zhi – who reigned from 146 to 168 CE – also known as Emperor Huan.

Archaeologists have known about the mysterious mausoleum for many years, and have long speculated that it may belong to Liu Zhi, but a seal discovered during the recent excavations may finally prove it. The seal contains the name of Emperor Liu Hong, Liu Zhi's successor. Historical records analysed by the researchers say Liu Hong constructed a mausoleum for Liu Zhi after his death, and the presence of this seal at the mausoleum suggests that it is that of Liu Zhi.

"Together with the previous documents about the location of the emperor's tomb, the discovery makes us almost certain that it is the tomb of Emperor Liu Zhi," Wang Xianqiu, an associate researcher at the Luoyang City Cultural Relics and Archaeology Research Institute, said. Emperor Liu Zhi ruled China during a time of great strife; there were frequent famines, rebellions and bloody purges of palace officials during his reign.

Records published by the Chinese historian Sima Guang in the 11th century and translated into English by Rafe de Crespigny in a book that was initially published in 1989, called *Emperor Huan and Emperor Ling*, tell of such famines and rebellions that ravaged China during Liu Zhi's reign. The emperor responded to the problems by periodically killing his palace officials. In 159 CE he executed Liang Ji, a senior official who had helped bring Liu Zhi to power. Most of Liang Ji's family was also killed by Liu Zhi, as were other officials in the following years.

The bloodletting did nothing to help the country's fortunes. Near the end of Liu Zhi's life his people became increasingly vocal about his shortcomings, despite the risk of being executed. In 166 CE, students studying for civil service exams staged protests, but troops stopped the protests and arrested them. The records also tell of bloody military campaigns resulting from the numerous rebellions.

Liu Zhi died in January 168 CE, at the age of 36. It's not clear what he died of, but historical records do not say that he was murdered. The mausoleum that he was eventually buried in was called the 'mound of comprehension'. The mausoleum is a complex made of stone and contains a number of corridors, yards and a drainage system. Originally it would have been covered by a mound made out of dirt. Excavations at the site are ongoing.

ANIMALS

Man tries to smuggle chameleons in socks

Words by **Nicoletta Lanese**

A man attempted to smuggle 74 protected chameleons through an Austrian airport by hiding the animals in socks and empty ice cream containers in his luggage. The man was caught at customs control in Vienna after travelling from Tanzania via Ethiopia. After authorities confiscated the colourful reptiles, the chameleons were taken to Vienna's Schönbrunn Zoo, but three of the animals sadly did not survive. The zoo identified all of the chameleons as originally being from the Usambara Mountains in Tanzania.

People regularly harvest Tanzanian chameleons from the Usambara Mountains to sell in the exotic pet trade, but not all do so legally. Legal trade of the animals requires a permit, and authorities limit the number of chameleons that can be collected and exported. The animals face rampant habitat loss, so if too many chameleons are taken from the region, they could ultimately be driven to extinction.

Most chameleons are protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which requires various certificates to legally trade the animals. For illegally stowing chameleons in socks and ice cream tubs, the man caught in Vienna will face a fine of up to around €6,000 (£5,300 or $7,270). The zoo did not note which species of chameleon the man tried to smuggle, but said they ranged from one-week olds to full-grown adults.


© Getty

It has not yet been identified which species of chameleon the man attempted to smuggle

SPACE

NASA finds 'Lost Galaxy' shining in Virgo

Words by **Brandon Speckter**

In the 1950s, when amateur astronomer Leland S. Copeland first fixed his telescope lens on a distant galaxy in Virgo, he saw an eerie spiral shrouded in dust. Copeland, a poet fond of writing about the cosmos, dubbed the spiral the 'Lost Galaxy', a name that stuck. Scientists know this galaxy as NGC 4535, one of the largest of the 2,000 or so galaxies in the Virgo Cluster, located about 50 million light years from Earth. When recently viewed through Hubble, the haze that clouded Copeland's Lost Galaxy vanished to reveal a vibrant sea of stars not so different from the Milky Way.

Like our home galaxy, the Lost Galaxy is a barred spiral: a vast swirl of stars with a distinct bar structure at its centre. The colours of those stars can tell us a bit about the galaxy's history. The yellowish glow of the galaxy's central bulge points the way to the Lost Galaxy's oldest and coldest retinue of stars; meanwhile, bright-blue clouds clustered together in the galaxy's spiral arms reveal where its hottest, youngest stars congregate, lighting up the gas and dust around them.

Today the Lost Galaxy is not hard to find. Its long, elegant arms make it a prime candidate for studying the structure of spiral galaxies. NASA released the image below on 11 January as part of an ongoing survey of 38 spiral galaxies located within 75 million light years of Earth.

The spiral galaxy NGC 4535 is better known as the 'Lost Galaxy' for its hazy appearance

It is the first time animals have been spotted by satellite against a complex geographical background

ANIMALS

Elephants counted from space using satellites and AI

Words by **Harry Baker**

Researchers combined high-resolution images captured 372 miles above Earth's surface by the satellites WorldView 3 and 4 with deep computer learning to count the number of elephants in Addo Elephant National Park in South Africa.

Typically, conservationists do this from low-flying planes in order to count and monitor African bush elephants (*Loxodonta africana*), a method that takes many hours. With the new technique, which combines satellite imagery with artificial intelligence, up to 1,930 square miles can be surveyed on a single blue-sky day in minutes. Next, the researchers' deep-learning computer algorithms analyse those images and pick out individual elephants. The results of this new proof-of-concept study showed the AI was as accurate as the human eye at spotting each elephant.

"While this is a proof of concept, it's ready to go," said Isla Duporge, a zoologist at the University of Oxford, said. "And conservation organisations are already interested in using this to replace surveys using aircraft." The new technique is a key part of ensuring the survival of this species, which is listed as vulnerable to extinction by the IUCN Red List, the world's leading database surrounding extinction threats to wildlife created by the International Union for Conservation of Nature (IUCN). Due to poaching and habitat destruction, just 415,000 African elephants roam the wild. "Accurate monitoring is essential if we're to save the species," Olga Isupova, a computer scientist at the University of Bath, who wrote the deep-learning algorithms used in the study, explained. "We need to know where the animals are and how many there are."

> "Accurate monitoring is essential if we're to save the species"

What really makes this study stand apart from other satellite-tracking projects is how successful the computer program was at picking out the elephants from their complex backgrounds, known in ecology as heterogeneous landscapes, including grasslands and partially tree-covered savannah. "This type of work has been done before with whales, but of course the ocean is all blue, so counting is a lot less challenging," Isupova said.

PLANET EARTH

CO_2 levels to pass an alarming milestone in 2021

Words by Harry Baker

Atmospheric carbon dioxide (CO_2) concentration will soar past a scary threshold this year, exceeding 417 parts per million (ppm), a 50 per cent increase since the start of widespread industrial activity in the 18th century. The forecast comes from the Met Office, the national meteorological service for the UK, which used data collected at Mauna Loa Observatory in Hawaii. Even though there was a slight decrease in global greenhouse gas emissions in 2020 because of the COVID-19 pandemic and the current La Niña event – a weather pattern in the Pacific that usually lowers global carbon emissions – it wasn't enough to offset previous increases.

"Since CO_2 stays in the atmosphere for a very long time, each year's emissions add to those from previous years and cause the amount of CO_2 in the atmosphere to keep increasing," said Richard Betts, head of the climate impacts group at the Met Office.

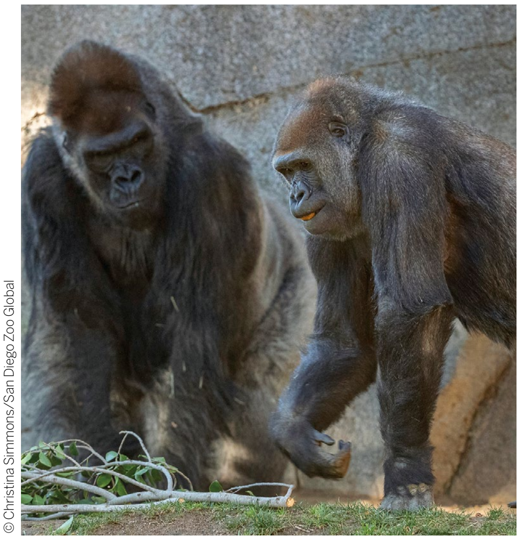
The concentration of CO_2 in the atmosphere follows predictable seasonal variations. Levels peak in May and then decrease over the summer as plants grow across the Northern Hemisphere and suck in carbon before rising again from September. Although the total amount of CO_2 emitted worldwide in 2020 was down seven per cent from previous years, emissions have almost returned to pre-pandemic levels.

The current La Niña event, which has been causing unusually cool weather since the middle of 2020, is also expected to reduce the rate of increase in CO_2 this year. This is due to a temporary increase in the amount of carbon stored in ecosystems like tropical forests, which grow more quickly in cooler conditions. However, that's still not enough to stop the planet from reaching the ominous CO_2 milestone this year.

Mauna Loa Observatory keeps the longest running continuous record of atmospheric CO_2 concentrations in the world. Since climate scientist Charles David Keeling started these records in 1958, scientists have used the data to track atmospheric CO_2 levels using the Keeling Curve, a graph that has become an iconic symbol of humanity's growing impact on the global climate system. That means we have a lot of work to do to meet the International Panel on Climate Change's goal of limiting global warming to 1.5 degrees Celsius above preindustrial levels.

We are approaching a 50 per cent increase from preindustrial times

© Getty



© Christina Simmons/San Diego Zoo Global

These cases are the first in the world reported among captive great apes

HEALTH

Gorillas at San Diego park catch COVID-19

Words by Rachael Rettner

Multiple gorillas at a San Diego zoo have tested positive for COVID-19 in what appear to be the first cases of captive great apes contracting the virus. Officials with the San Diego Zoo Safari Park said that eight of their gorillas are believed to be infected with the coronavirus that causes COVID-19. At least two gorillas have tested positive, and staff are working under the assumption that all of the gorillas could be infected.

On 6 January, zoo staff noticed that two of the park's gorillas were coughing. Subsequent testing of faecal samples from the gorillas revealed the presence of SARS-CoV-2 in the gorilla troop. "Aside from some congestion and coughing, the gorillas are doing well," said Lisa Peterson, executive director of San Diego Zoo Safari Park. "The troop remains quarantined together and are eating and drinking. We are hopeful for a full recovery."

Park officials believe the gorillas caught the virus from an asymptomatic staff member who also tested positive for the virus. It appears to be the first reported case of natural transmission of COVID-19 to great apes. But other animals have contracted COVID-19 on occasion, including cats, dogs and minks. In April 2020, a tiger at the Bronx Zoo in New York City tested positive for COVID-19, and multiple other tigers there showed symptoms.

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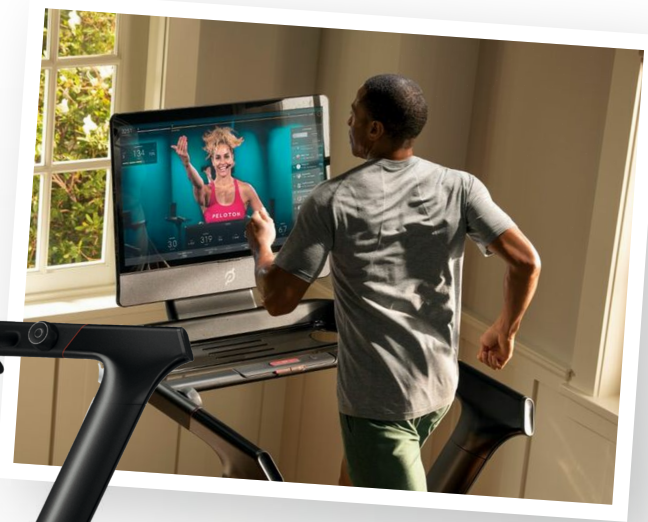
WISH LIST

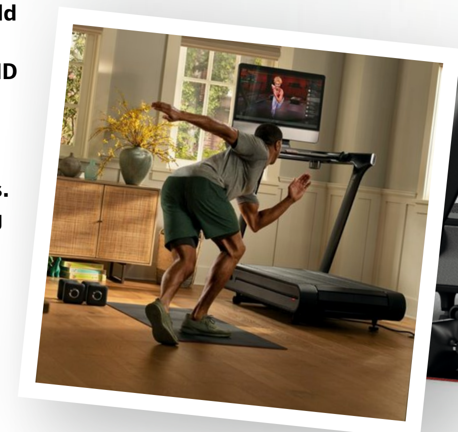
The latest FITNESS gadgets



Peloton Tread

■ Price: **From £2,295 / $2,495**
www.onepeloton.com

The Peloton Tread isn't an ordinary treadmill – it's a home-workout system that lets you join in with trainers around the world for prerecorded and live exercise classes. The 23.8" HD touchscreen and immersive front-facing speakers allow you to become immersed in thousands of running classes. The Peloton Tread is bursting with analytic abilities and can monitor your speed, distance, heart rate, time and calorie burn, building a fitness profile while keeping track of your progress.



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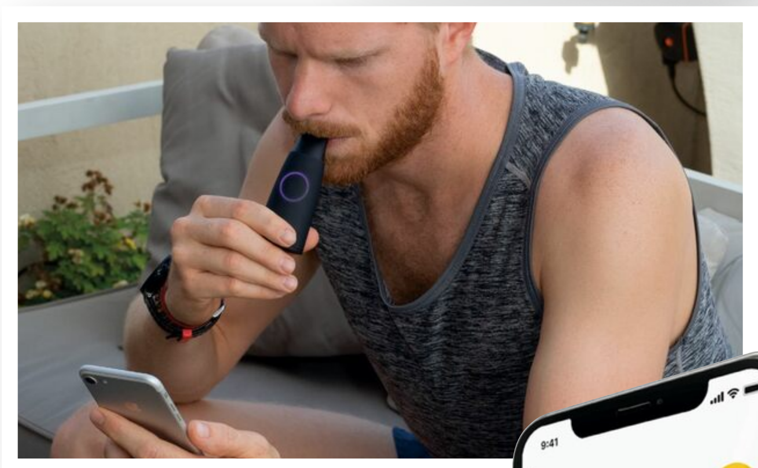

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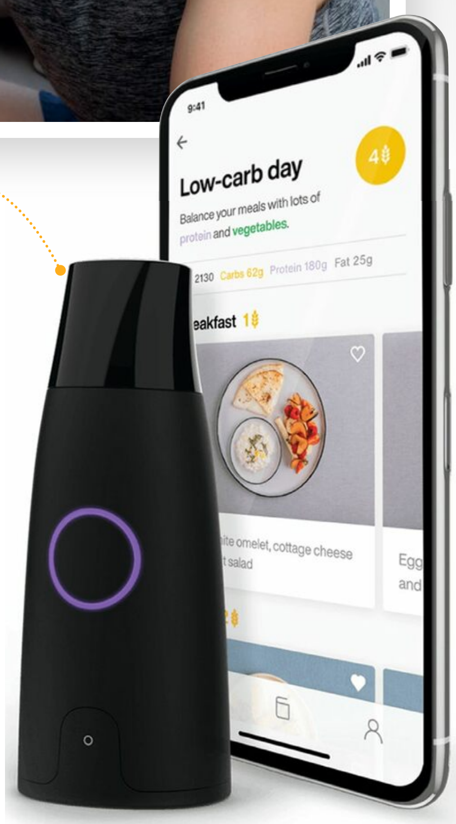


Lumen

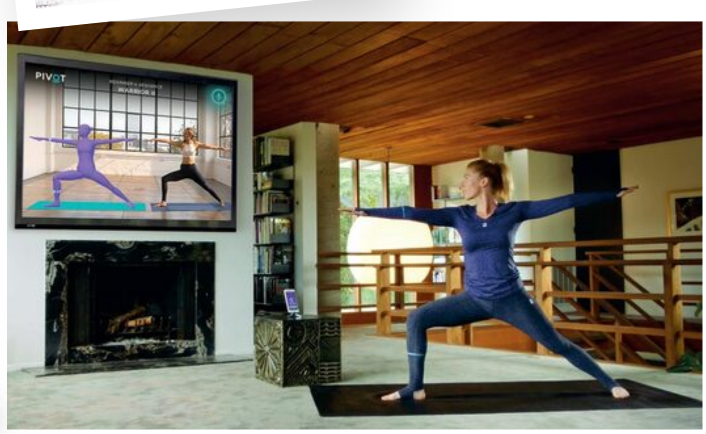
■ Price: **£349 (approx. $476)**
www.lumen.me

This pocket-sized nutritional breathalyser is designed to offer insight into your body's metabolism. The Lumen claims to measure the carbon dioxide (CO_2) in a single breath to determine whether the body is burning carbohydrates or fats. For example, a high concentration of CO_2 indicates you're burning carbohydrates, and low CO_2 suggests fat burning. The support app allows you to monitor and track how your metabolism works and offers nutritional recommendations.

PIVOT Yoga

■ Price: **From $99 (approx. £72.50)**
www.pivot.yoga

This high-tech yoga outfit is designed to give you real-time feedback of your yoga positions and progress. Simply calibrate the outfit with the accompanying app and follow the instructions of a virtual teacher. By analysing your form, the online teacher will compare your position with an optimal one so you can improve your yoga skills. PIVOT does this by using 16 sensors integrated into the clothing that measure the angle, rotation and distance of your arms and legs.



© Pivot Yoga

HidrateSpark STEEL

© Hidrate Inc

■ Price: £69.99 / $64.99
www.hidratespark.com

There are so many water bottles to choose from, but the HidrateSpark STEEL is a high-tech upgrade. This vacuum-insulated bottle promises to keep water cool for up to 24 hours. It also comes equipped with an LED smart sensor that lights up the base of the smart bottle when it's time to take a sip. With the companion app, HidrateSpark tracks your water intake, sets reminders and even integrates with a variety of other fitness trackers and gadgets, such as Apple Watch and Fitbit.

© Moov

Moov HR Sweat

■ Price: $99.95 / £72.97
www.welcome.moov.cc

Moov HR Sweat is a heart rate-powered sweatband that not only catches beads of perspiration but also uses an EKG-level heart rate monitor to help you track your heart health. The smart band claims to measure exact heart rate from the temples using oximeter technology. The accompanying app allows you to track your heart rate, calorie burn and workout progress, as well as providing an audible coach to help you along during a run.


© PowerDot

PowerDot 2.0

■ Price: £185 / $199
www.powerdot.com

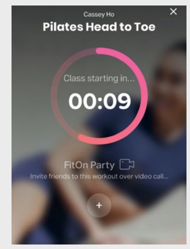
The PowerDot 2.0 is designed for post-workout relief and recovery. The compact and portable smart stimulation device promises to help increase blood circulation and deliver oxygenated and nutrient-rich blood to the muscles to improve recovery. It also claims that by using Neuromuscular Electrical Stimulation (NMES) it can wash away the cellular debris produced by the body's inflammatory response after exercise, which reduces pain. Along with helping the release of endorphins and interrupting pain signals in the body's nervous system, PowerDot appears to be the latest in recovery tech.

APPS & TOOLS

FitOn

■ Developer: **FitOn Inc**
■ Price: **Free / Google Play/ App Store**

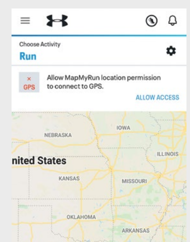
This at-home exercise tool is packed with classes, advice and personalisable workout plans to keep you on track for your fitness goals.



Map My Run

■ Developer: **MapMyFitness Inc**
■ Price: **Free / Google Play/ App Store**

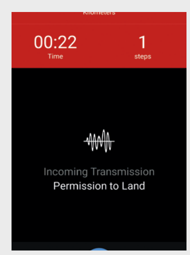
If you're a keen runner, this app is a must have. It's full of tools to track your runs, from mapping out your route to monitoring your speed and distance.



Zombies, Run!

■ Developer: **Six to Start**
■ Price: **Free / Google Play/ App Store**

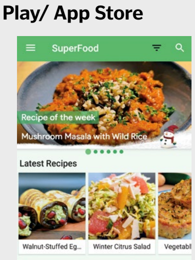
Running can be a little repetitive. But this app injects some fun and fear into your runs by playing audible zombie attack scenarios.



SuperFood

■ Developer: **JuniSmile Food**
■ Price: **Free / Google Play/ App Store**

This app provides healthy, nutritious recipes and meal plans and helps you create healthy grocery lists. It can also help you track your daily intake.



DEAD RADIAT

DID YOU KNOW? *Radioactivity was discovered when a uranium sample left an imprint on unexposed photographic film*

FROM DENTAL X-RAYS TO NUCLEAR REACTORS: EVERYTHING YOU NEED TO KNOW ABOUT IONISING RADIATION, ITS USES AND HAZARDS

Words by **Andrew May**

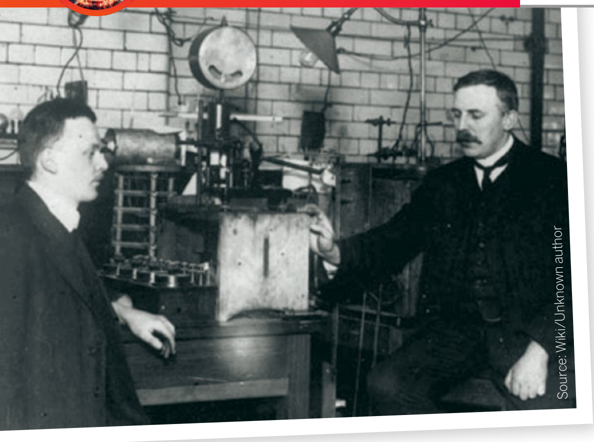
For many, the word 'radiation' can set alarm bells ringing. If you think of the terrible death toll of the Hiroshima and Nagasaki bombs, or the devastating environmental effects of the Chernobyl nuclear disaster, it's easy to see why. Events like these show just how lethal radiation can be. But radiation is around us all the time – most of it completely harmless, and much of it positively beneficial.

In its broadest sense, radiation refers to any form of emitted energy that travels outwards – or radiates – from a source. It can take the form of streams of fast-moving particles, such as those emitted by radioactive materials, or of the electromagnetic (EM) waves generated when electrons jump from one energy level to another inside atoms. The heat and light we receive from the Sun come to us in the form of EM radiation, and life on Earth would be impossible without these particular forms of radiation.

There are other types of EM radiation that we can produce by technological means, such as radio for communication, microwaves for cooking or X-rays for medical imaging. Although these are created and used in different ways, they are all essentially the same type of wave, travelling from A to B at the same speed – the speed of light. The difference lies in wavelength and frequency. EM radiation has a spectrum ranging from radio waves at the low frequency, long-wavelength end to X-rays and gamma rays at the high frequency, short wavelength.

Any kind of EM radiation can be dangerous if enough energy is pumped into it. You see hazard warnings on microwave ovens, for example, and on lasers – which are

10,000,000
Ratio of wavelengths of microwaves to X-rays



Hans Geiger (left) with Ernest Rutherford, who named alpha, beta and gamma radiation

simply an intense beam of light. But there's a subtlety which makes the high-frequency end of the EM spectrum substantially more dangerous than the lower end. This stems from the fact that EM radiation is fundamentally bipolar – the so-called 'wave-particle duality'. Although it travels from its source to its destination exactly as if it were a wave, when it gets there it passes on its energy as if it were packaged up in discrete particles, called photons. The higher the frequency, the more energy each photon carries. If you have a microwave beam and an X-ray beam with the same total energy, the microwave energy will be spread out over millions of times more photons.

The significance of discrete photons lies in the effect they have when they hit atoms at the receiving end. If there are a lot of low-energy photons, as in a microwave beam, they just cause the atoms to vibrate a bit more, which has the effect of increasing the temperature. The same is true of infrared radiation, which lies between microwaves and visible light in the spectrum, and is the principal way that the Sun heats the Earth. When you feel warm sunshine on your face, it's because the photons are causing the atoms to jiggle about just that bit more. It's different on the other side of the visible spectrum, where we find higher frequency ultraviolet (UV) radiation. UV photons carry enough energy to produce internal changes in atomic structure, boosting electrons to higher energy levels and altering molecular bonds. This can potentially cause DNA damage, which is

"THE EARTH IS UNDER CONSTANT BOMBARDMENT FROM COSMIC RADIATION"

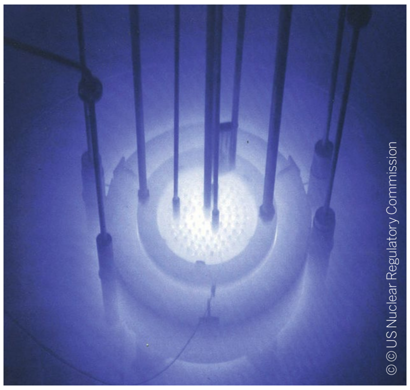
400x
Radioactivity from Chernobyl exceeded the Hiroshima bomb

Ten electronvolts
Minimum energy for a photon to ionise an atom

That spooky blue glow

Although ionising radiation is invisible, we sometimes see its effects on surrounding material. Old-style radioluminescent paint glows because it's slightly radioactive, stimulating light emission from the paint molecules. More spectacularly, water-cooled nuclear reactors emit an eerie blue glow called Cherenkov radiation. This isn't dangerous itself – it's just ordinary light – but it's caused by super-fast beta particles that would be harmful if they weren't absorbed by the water, which has a protective as well as cooling function.

The beta particles travel close to the speed of light, but paradoxically the light itself doesn't. That's because light slows down to three-quarters of its normal speed when it travels through water. The result is a shock wave – like the sonic boom caused by an aircraft travelling faster than the speed of sound – and that's what we see as the characteristic Cherenkov glow.

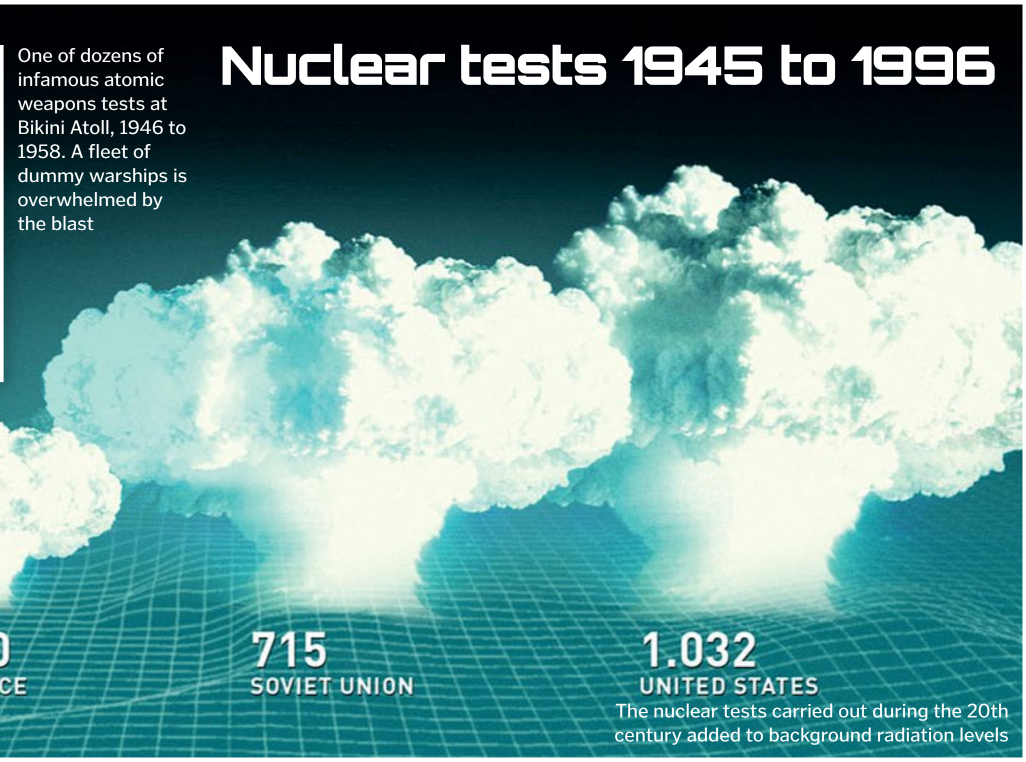


Cherenkov radiation surrounding the core of an underwater nuclear reactor

AR ZONE! SCAN HERE

One of dozens of infamous atomic weapons tests at Bikini Atoll, 1946 to 1958. A fleet of dummy warships is overwhelmed by the blast

Nuclear tests 1945 to 1996



The nuclear tests carried out during the 20th century added to background radiation levels

Radiation shielding

Some types of ionising radiation are easier to block than others

Alpha particles

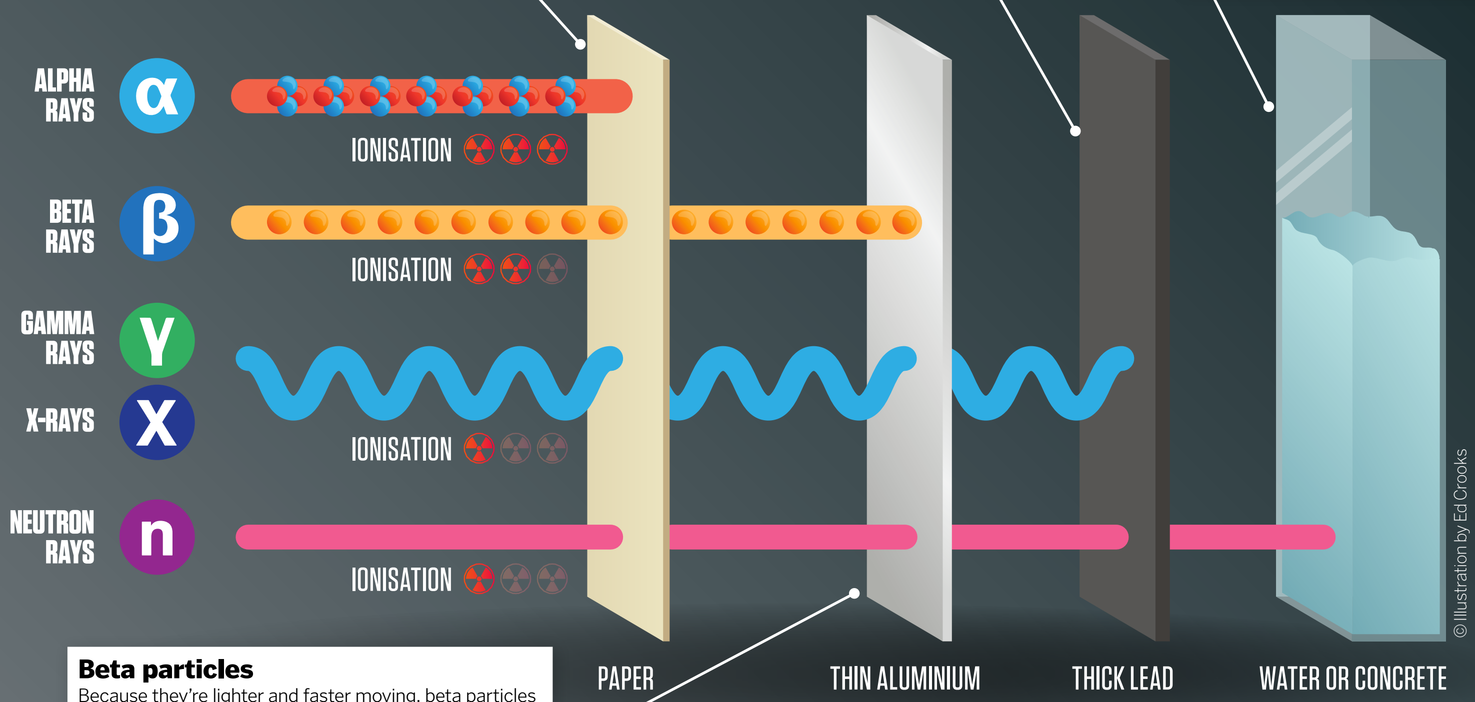
Of the two types of particle radiation emitted by radioactive materials, alpha rays are the easiest to stop. A thin sheet of paper will do it – or, if you want to live dangerously, a human hand.

Gamma rays

The third type of radiation emitted by radioactive substances is even harder to block, because it consists of EM waves rather than particles. But even gamma rays can be stopped by a few centimetres of lead shielding.

Neutron radiation

The fast neutrons created in a nuclear reactor are the hardest type of radiation to stop. Heavy elements like lead aren't as effective as light ones like hydrogen, so reactors are shielded by several metres of hydrogen-rich concrete or water.



Beta particles

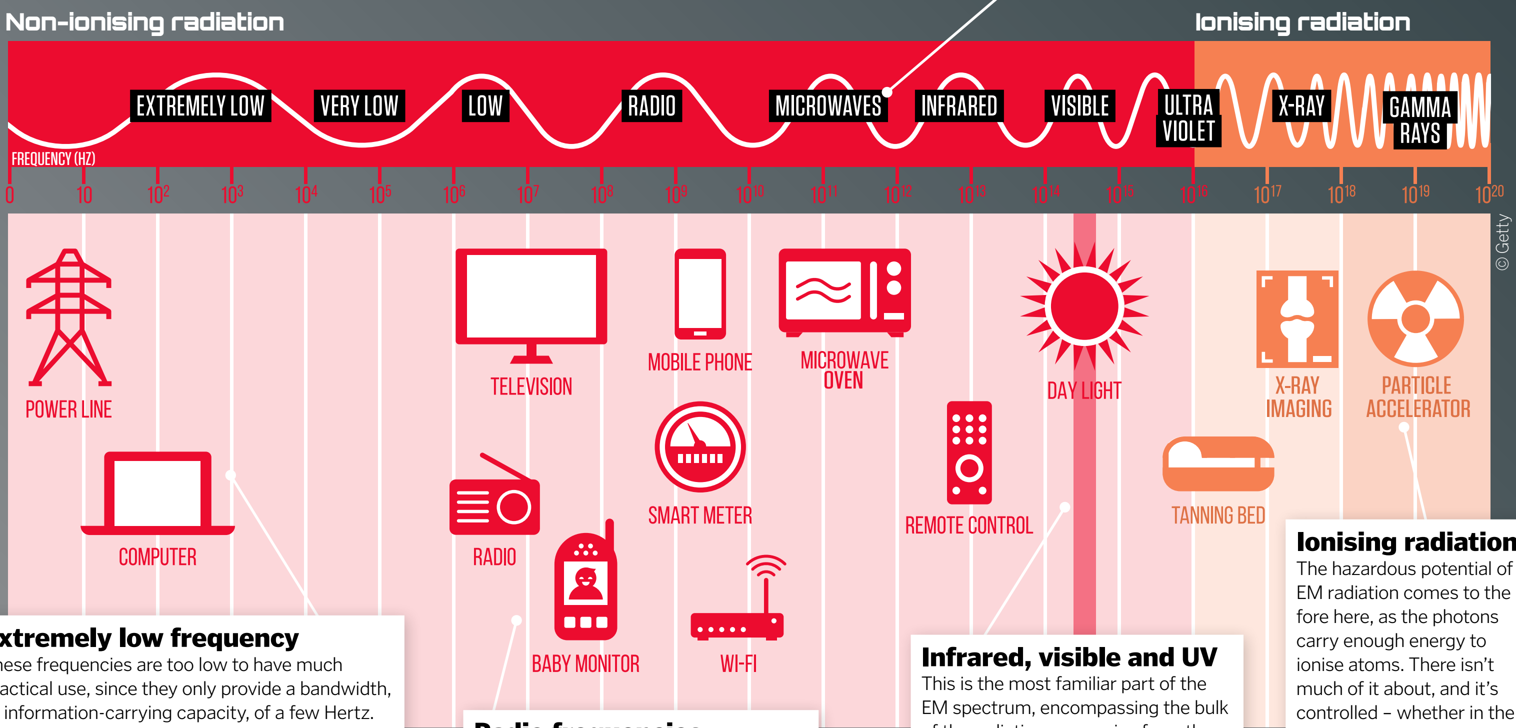
Because they're lighter and faster moving, beta particles have greater penetrating power. They pass through paper easily, but they can still be stopped by a sheet of aluminium just a few millimetres in thickness.

The electromagnetic spectrum

The EM spectrum spans a vast range of phenomena and technologies

Microwaves

Most commonly associated with microwave ovens, these frequencies – corresponding to wavelengths of a few centimetres – are also used by communication systems such as mobile phones and Wi-Fi. It's at this point that overexposure starts to become hazardous.



Extremely low frequency

These frequencies are too low to have much practical use, since they only provide a bandwidth, or information-carrying capacity, of a few Hertz. Nevertheless, the fact that they can penetrate through water makes them useful in communicating with submarines. They're also produced by natural phenomena such as lightning.

Radio frequencies

At the lower end, used for AM radio, the bandwidth is still relatively small, so audio quality is poorer than in the higher frequency FM band. The top end of the range is used for TV broadcasting.

Infrared, visible and UV

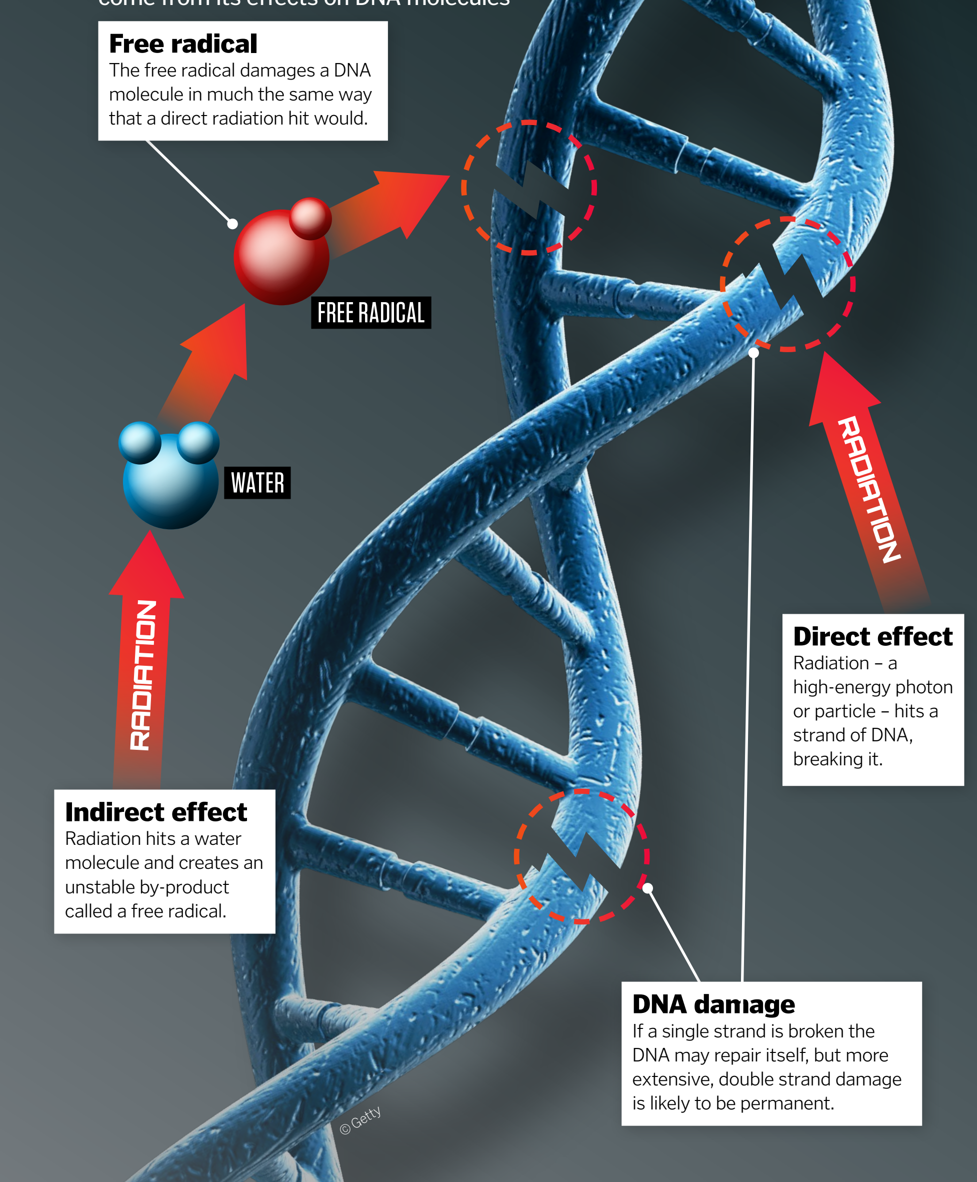
This is the most familiar part of the EM spectrum, encompassing the bulk of the radiation we receive from the Sun. We feel infrared as heat, our eyes use visible light to see and UV – which is harmful if we're overexposed to it – is what gives us a suntan.

Ionising radiation

The hazardous potential of EM radiation comes to the fore here, as the photons carry enough energy to ionise atoms. There isn't much of it about, and it's controlled – whether in the form of X-rays from a hospital scanner or gamma rays from a nuclear reactor.

How radiation damages DNA

The health hazards of ionising radiation come from its effects on DNA molecules



An important use of X-rays is as a diagnostic tool looking inside the human body

© Getty

1895
Wilhelm Röntgen discovered ionising radiation in the form of X-rays

why we have to wear sunscreen when UV levels are high.

As we go further up the frequency spectrum, we get to a point where individual photons have so much energy they don't simply boost electrons to higher levels inside an atom, they knock them out of the atom altogether. Because electrons carry a negative electric charge, this turns the atom into a positively charged ion. This process is referred to as ionisation. Radiation capable of achieving this is called – predictably enough – ionising radiation, and it's what people are really thinking of when they associate radiation with danger.

X-rays, which come above UV in the EM frequency spectrum, are an example of ionising radiation. They can cause DNA damage and other medical problems – but only if the amount received is high enough. In small doses, such as you might receive in a dental X-ray or hospital scan, there's nothing to worry about. In fact, the best known property of X-rays – that they travel through soft tissue as if it was transparent – has been a huge boon to medical science.

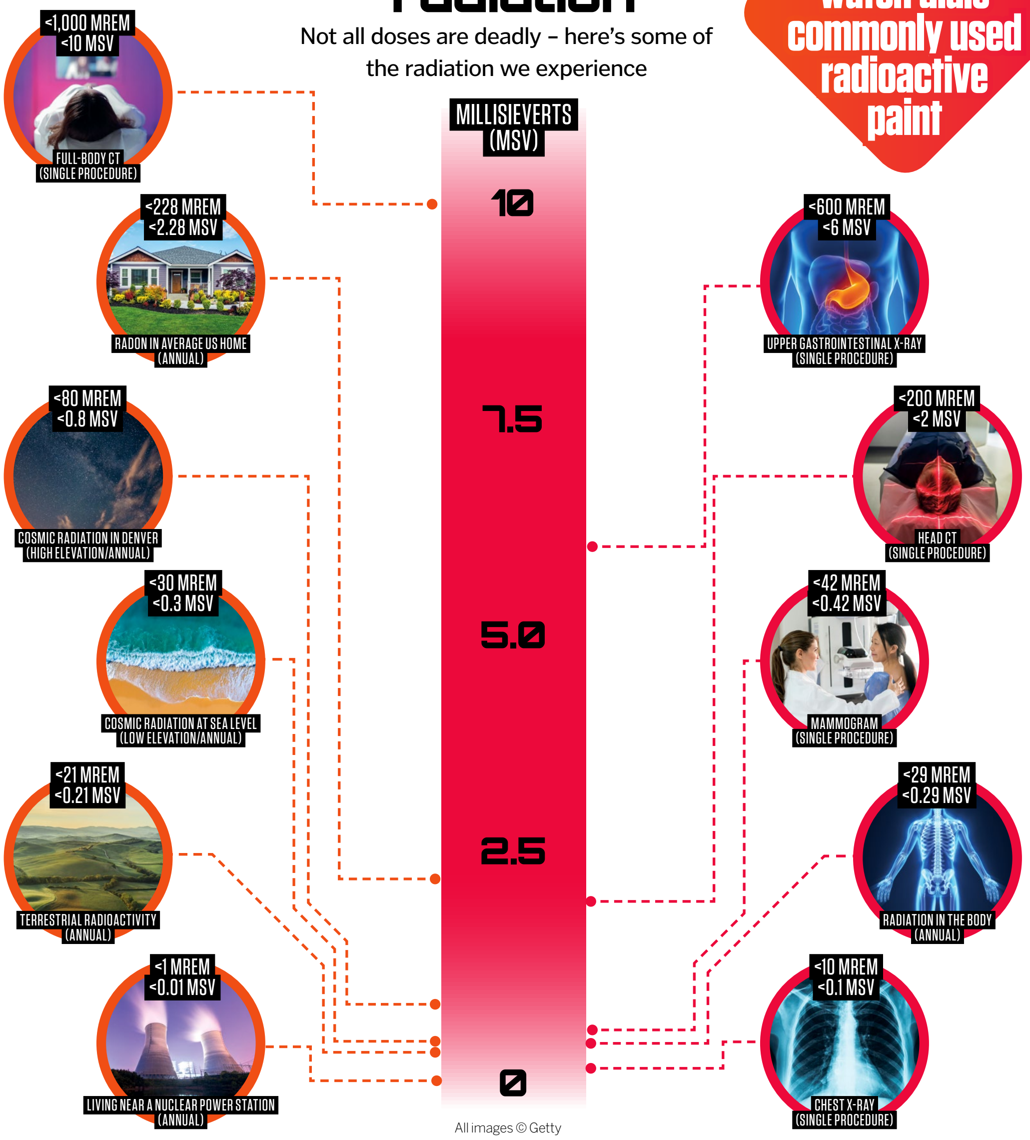
When X-rays were first discovered by physicist Wilhelm Röntgen on 8 November 1895, he gave them that name – 'X' for unknown – because he had no idea what they were. On the other hand, it was obvious right away that they were incredibly useful. The first recorded use of X-rays for a medical diagnosis was on 11 January 1896, just nine weeks later. That's the quickest that a brand-new scientific discovery has ever found a practical application.

X-rays are produced by electronic means, just as microwaves, light and UV can be. But when we get to the top end of the EM spectrum, the photon energies are so huge they can only be created by processes inside the atomic nucleus. This is the fearsome gamma radiation that's produced, among other things, by nuclear bombs. But gamma rays don't have to originate in a tremendous explosion. At a much lower level, they're given off spontaneously by certain elements that have unstable nuclei in a process known as radioactivity. Some radioactive elements can only be produced artificially – for example in a nuclear explosion or a nuclear reactor – but others occur naturally. These natural sources of radioactivity, of which uranium is the best known, are around us all the time, albeit in relatively small quantities.

Classical scholars will be aware that gamma is the third letter of the Greek alphabet after alpha and beta. So where do alpha and beta radiation come into the picture? They're also forms of ionising radiation given off by radioactive substances, but they're not part of the EM

Everyday radiation

Not all doses are deadly – here's some of the radiation we experience



All images © Getty

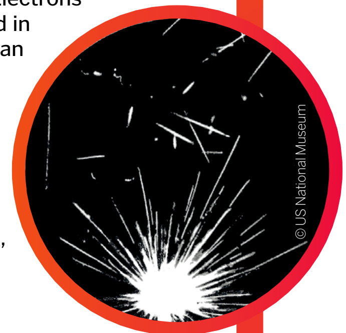
A century ago, luminous watch dials commonly used radioactive paint

Even radio-frequency radiation can be hazardous right next to a powerful transmitter

Source: Wiki/ Tom.jennings

Alpha and beta radiation

Unlike gamma rays, which are EM waves, the two other types of radiation emitted by radioactive substances consist of particles thrown out from unstable atomic nuclei. The nucleus is a dense clump of positively charged protons and electrically neutral neutrons. An alpha particle is composed of two neutrons and two protons, giving it a net positive charge and a relatively hefty mass. A beta particle is a fast-moving electron, which is much lighter and has a negative charge. Electrons are normally found in the outer parts of an atom, outside the nucleus, but beta particles are created by reactions inside the nucleus itself.



An early photograph, from 1915, of alpha particle tracks in a cloud chamber

© US National Museum

Measuring radiation

From a health-and-safety point of view, it's important to know how much ionising radiation is present in an environment. The most familiar way to measure this is the Geiger counter, which simply counts the number of ionising particles reaching it. But this isn't the best indication of danger level because it doesn't distinguish between high- and low-energy particles. A more refined alternative is the electronic dosimeter, which measures the cumulative energy received from ionising radiation in units called sieverts, with a fatal dose being about eight sieverts. For comparison, a dental X-ray gives you about five-millionths of a sievert, while you normally get twice that in the course of a day from natural background sources of radiation.

© Getty

A dosimeter being used to check radiation levels at the site of the Chernobyl disaster

spectrum. Rather than photons, they consist of streams of material particles: helium nuclei in the case of alpha rays and electrons in beta rays. What happens in radioactive decay is that an unstable nucleus spontaneously transforms into a more stable form, ejecting a photon or fast-moving particle in the process.

Alpha, beta and gamma rays were discovered in quick succession in the late 1800s and early 1900s, and were given their names by the 'father of nuclear physics', Ernest Rutherford. If you're interested in physics you've probably heard of him, but even if you aren't you'll be familiar with the name of one of his assistants at the University of Manchester, Hans Geiger. With Rutherford's help, he designed the first gadget for counting particles emitted by a radioactive sample. Geiger counters are still in use today, along with a range of more modern devices for measuring radiation levels – but the ominous clicks of a Geiger counter have become so familiar through movies and TV that the term is often used loosely for all such devices.

If Geiger counters had existed centuries ago, they still would have given off the occasional click. That's because there's always a low background level of ionising radiation from natural sources. Some types of rock, such as granite, contain tiny traces of uranium and other radioactive elements. The Earth is also under constant bombardment from cosmic radiation, emanating both from the Sun and from more distant parts of the universe. This includes fast-moving protons and other high-energy particles, as well as X-rays and gamma rays. But the amount reaching the Earth's surface is much too small to pose any health risks.

Since the second half of the 20th century, the level of background radiation has been boosted by nuclear weapons tests carried out between the 1940s and 1990s. The immediate radiation created by the explosions is long gone, but the blasts also produced a 'fallout' of radioactive material that has lingering effects to this day. The same is also true of the radioactive fallout produced by major incidents at nuclear power plants, such as Chernobyl in 1986 and Fukushima in 2011. These notoriously added to background radiation levels over a wide area.

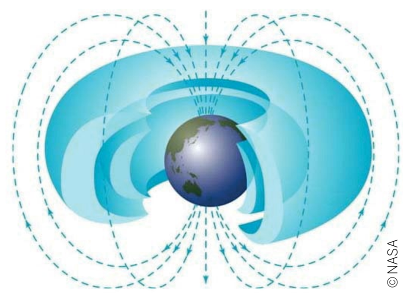
1 million
Number of dental X-rays needed for a fatal radiation dose

Given the enormous potential of nuclear power to reduce worldwide carbon emissions, it's a tragedy when accidents like these cause so much damage to the environment. But the fact is that both Chernobyl and Fukushima were the result of human error – compounded, but not caused, in the latter case, by an earthquake and tsunami. If a nuclear power station is properly designed and correctly operated, there's no reason why it should leak any radiation into the environment at all.

Radiation in space

While EM radiation travels in straight lines, that's not always true of charged particles, which can be deflected by magnetism. This has a welcome effect on Earth, because the geomagnetic field shields us from the high-energy protons and electrons constantly streaming out from the Sun. But not all of that radiation is bounced harmlessly back into space – some of it gets trapped in doughnut-shaped rings around the Earth. Called the Van Allen belts, these start well above the altitude of the International Space Station, but they do pose a potential hazard for astronauts passing through them en route to more distant destinations.

Fortunately, a fast-moving spacecraft will only be inside the belts for an hour or so. In the case of the Apollo astronauts, NASA estimates they were exposed to 0.16 sieverts on their passage through the radiation belts – a relatively high dose, but still only about a fiftieth of the fatal level.

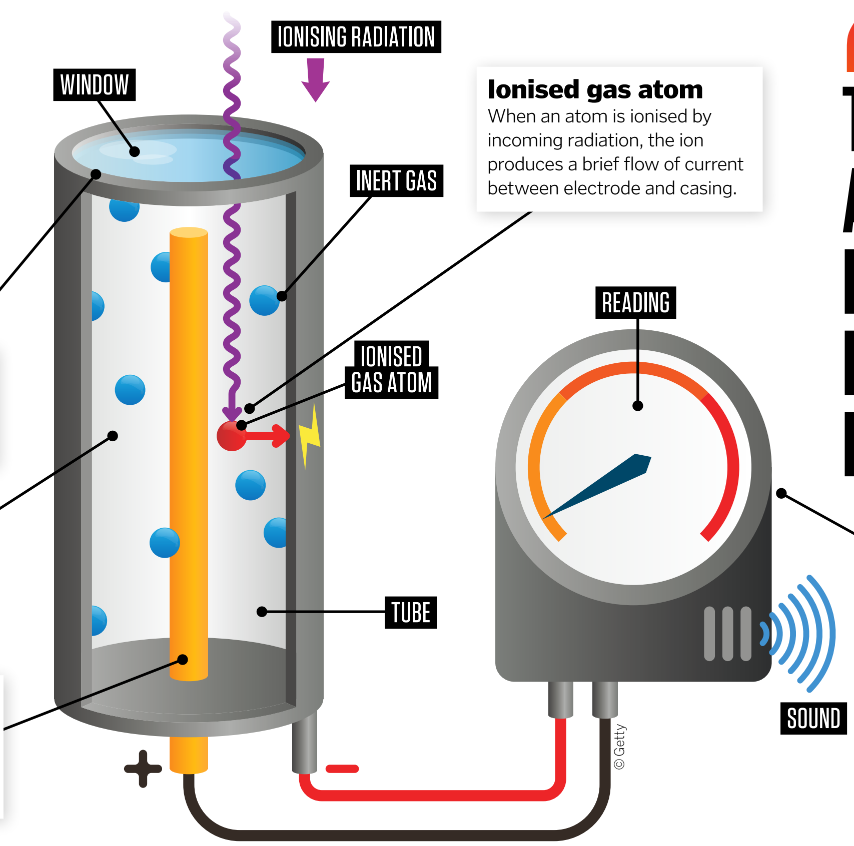


© NASA

The Earth's magnetic field traps radiation in the doughnut-like Van Allen belts

How Geiger counters work

The oldest way to measure ionising radiation uses that very same property



Ionised gas atom
When an atom is ionised by incoming radiation, the ion produces a brief flow of current between electrode and casing.

Mica window
The ionising particles enter through a thin mica window at one end of the tube.

Gas-filled tube
The main sensor consists of a metal-lined tube filled with an inert gas at low pressure.

Central electrode
Running through the middle of the tube is a metal electrode, held at high voltage relative to the casing.

Counter
The resulting electrical pulse is amplified to an audible click, and displayed on the meter at the same time.

© Getty

"THERE'S ALWAYS A LOW BACKGROUND LEVEL OF RADIATION"

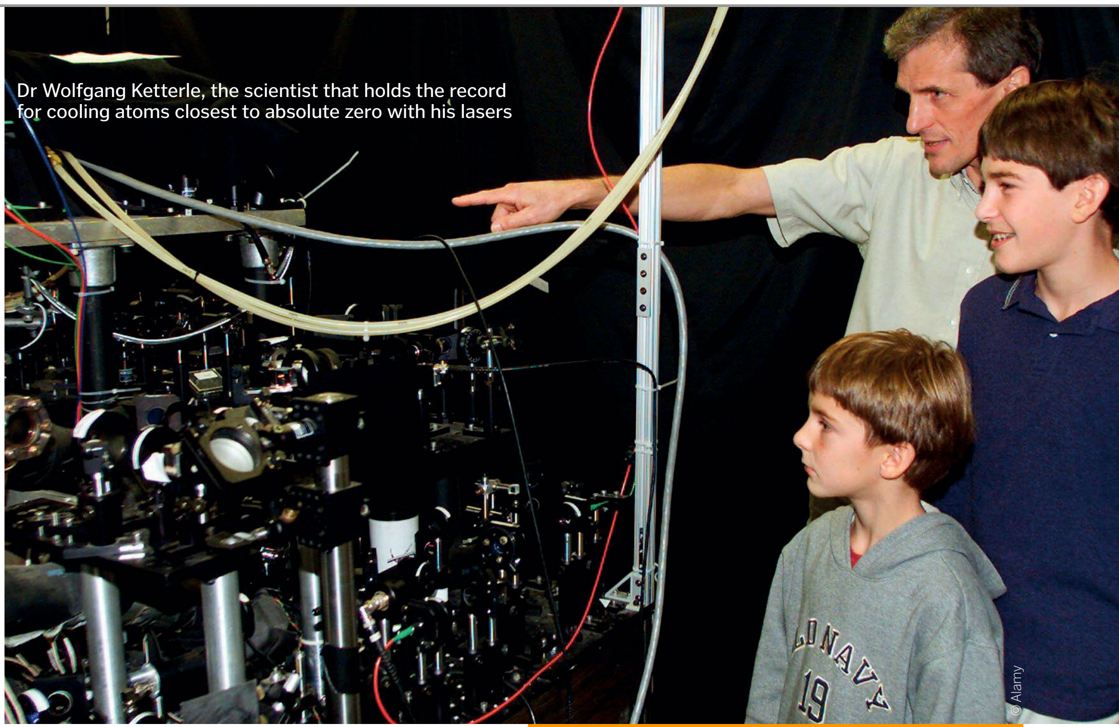
Water is excellent at blocking radiation due to its hydrogen molecules. This is the Advanced Test Reactor in Idaho. It's submerged in water, generating the blue glow of Cherenkov radiation

Laser stands for Light Amplification by Stimulated Emission of Radiation

EXTREME TEMPERATURES

Why leaving our usual range of warm and cold makes materials do strange and exciting things

Words by **Andy Extance**



Dr Wolfgang Ketterle, the scientist that holds the record for cooling atoms closest to absolute zero with his lasers

© Alamy

You might be surprised by how mind-bending the idea of temperature can be, even though it's such an obvious part of our everyday lives. Few things are as easy to imagine as the shivering cold in winter and the warming sunlight in summer. But we live within a narrow range of all the temperatures that are possible. Outside of this Goldilocks window lie hot and cold extremes where everything becomes very strange. Go cold enough and the air around us would turn solid, turning everything into a single giant brick. Go hot enough and atoms no longer hold together, creating weird states of matter that we could not survive an encounter with.

Even temperature itself is a strange idea. We use the word to talk about how energy affects matter, the physical stuff that makes up the universe. Temperature rises when energy flows into matter, and falls when it leaves. In our everyday lives, as an object's temperature rises the atoms and molecules inside it jiggle around more. As its temperature cools, atoms and molecules in the object jiggle more slowly, becoming stiller. You can show this by dropping food colouring into water. The hotter the water is, the faster the colouring will spread, because water molecules are jiggling around and jostling it more.

Scientists care so much about this they've invented several temperature scales to measure it. Two common scales break up temperature into degrees Celsius or Kelvin. These scales are similar, with the difference between one and two degrees Celsius the same as the difference between one and two Kelvin. The point at which water molecules slow down enough to go from liquid to solid is zero degrees Celsius, but that corresponds to 273.15 Kelvin. That is because the Kelvin scale starts at what is supposed to be the lowest temperature anything can reach – zero Kelvin, which is -273.15 degrees Celsius. Here all atoms would be perfectly still, but physics gets weird and messes up that idea. Many scientists think that nothing can actually reach zero Kelvin, but others have suggested that negative temperatures on the Kelvin scale might be possible. Either way, a colder world would be very different long before that. Most of the air we breathe is made up of nitrogen gas, which turns liquid at 77 Kelvin and solid at 63 Kelvin.

In the other direction, it's easy to imagine that heating matter up makes its atoms and molecules move ever faster. But at temperatures of thousands of Kelvin, like you find on the surface of stars, the heat will make molecules fall apart into the atoms they're made of. If you continue to turn up the heat, the atoms themselves will fall apart, leading to ionised plasma. And scientists think that you can, in principle, go much higher. Theories say that at 2 billion Kelvin and beyond, the nucleus at every atom's heart will fall apart. The upper temperature limits are very high indeed, imposed by the universe running out of energy, or changing its nature altogether. Such hot prospects are truly awesome to imagine.

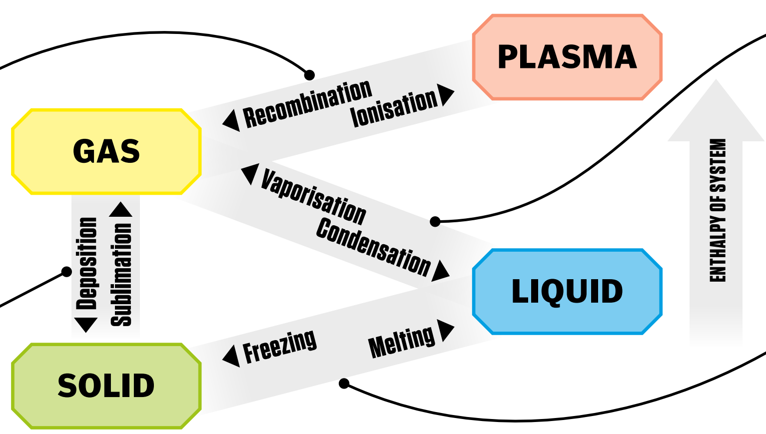
Absolutely impossible zero

According to traditional science, absolute zero is the coldest possible temperature. When atoms and molecules are near absolute zero, they should stop moving altogether. But scientists cannot fully achieve this state of zero heat energy in a substance. That's because at this extreme of temperature, physics gets very strange.

Quantum physics laws, which govern how electrons behave, say that there must always be some energy to make molecules move. The same weird principles led scientists to suggest that negative temperatures on the Kelvin scale might be possible. This idea is controversial. Such negative Kelvin temperatures have never been measured, and scientists argue over whether or not they can really exist. Researchers have shown, however, that molecules cooled to near absolute zero can react chemically. That shouldn't be possible according to traditional science, but weird quantum physics effects allow it to happen.

Cold or hot stuff?

Changing matter's temperature affects its energy, pushing it through phase transitions between different states



Ionisation and recombination
Rare on Earth, plasma forms naturally in stars. There, high temperatures strip electrons from atoms, ionising them. At lower temperatures the electrons and the atoms' nuclei recombine into a gas.

Sublimation and deposition
Materials like solid carbon dioxide, or dry ice, sublime into a gassy cloud without going through a liquid form. The reverse process straight from gas to solid is called deposition.

Vaporisation and condensation
Steam rising from a kettle originates as liquid water vaporises. Condensation is the reverse phase change, such as water droplets forming from vapour on colder tiles next to a kettle.

Melting and freezing
Changes from solid to liquid and back as substances melt and freeze are perhaps the most familiar phase transitions. Think of ice melting then turning solid again in the freezer.

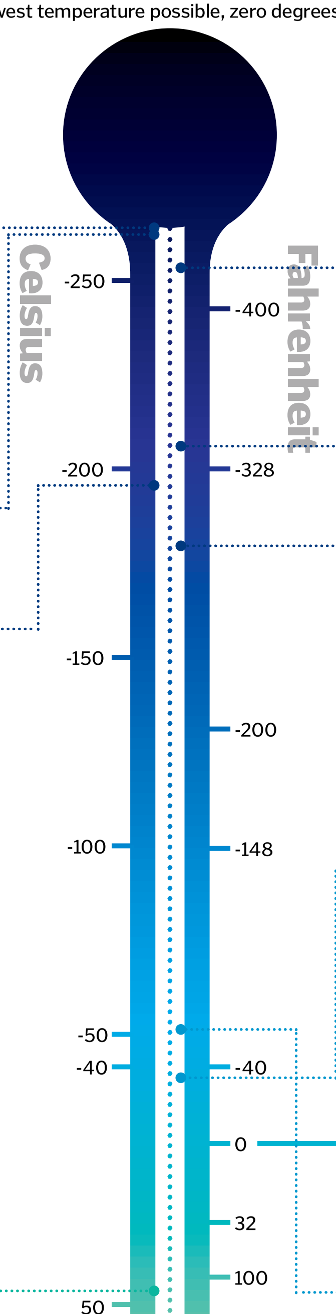
Taking the universe's temperature

The wide range of possible temperatures makes familiar materials do strange things

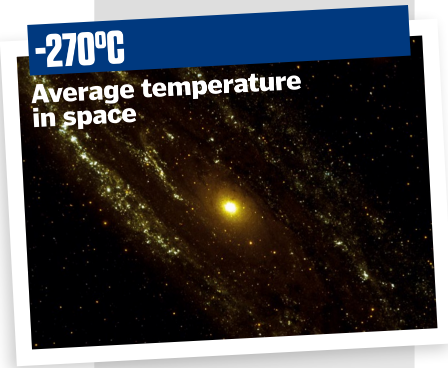
Absolute zero

-273.15°C (-459.67°F)

The lowest temperature possible, zero degrees Kelvin.



PLASMA



-270°C

Average temperature in space

46°C

Cold plasma

Tiny points of plasma can be made at relatively low temperatures using electricity to strip electrons from gases such as argon.

5,500°C

Sun's surface

The heat generated as the Sun fuses hydrogen to make helium creates a plasma that flies away as the 'solar wind'.

GAS

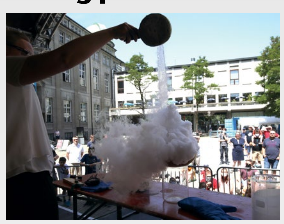
-273.15°C

Coldest human-made temperature

Using laser light and complicated magnetic fields to confine sodium atoms, scientists have lowered their energy until they almost stop moving.

-196°C

Nitrogen boiling point



"Cold enough, and the air around us would turn solid"

LIQUID

-269°C

Helium boiling point

Helium has the lowest boiling point of any element. It is a weird liquid down to -272.2 degrees Celsius, when it solidifies.

-179°C

Methane rain on Titan

Titan, one of Saturn's moons, is so cold it is covered in lakes and oceans of what we call natural gases, such as ethane and methane, on Earth. Yet Titan's weather seems otherwise similar to ours, with methane and ethane rain common in many places on its surface. Overall, Titan contains hundreds of times the amount of the natural gas and oil found on Earth.

-39°C

Mercury melting point

Mercury has the lowest melting point of any metal, remaining as a liquid at temperatures when water turns into ice.

SOLID

-210°C

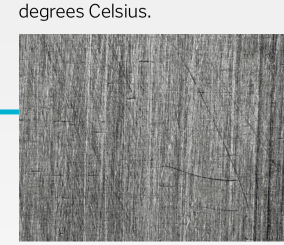
Nitrogen melting point

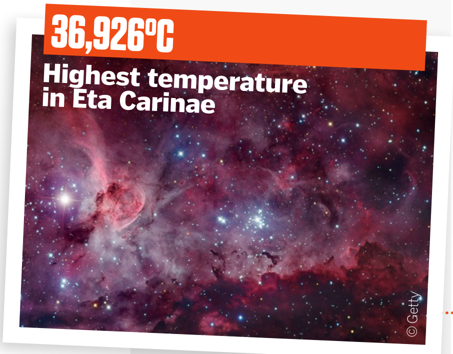
The air we breathe is mainly nitrogen, but if it were cooled to -210 degrees Celsius it would become a solid brick.

-50°C

Steel cracking

High-strength steels become brittle at low temperatures, breaking easily. This happens to even the strongest grades at -50 degrees Celsius.





36,926°C
Highest temperature in Eta Carinae

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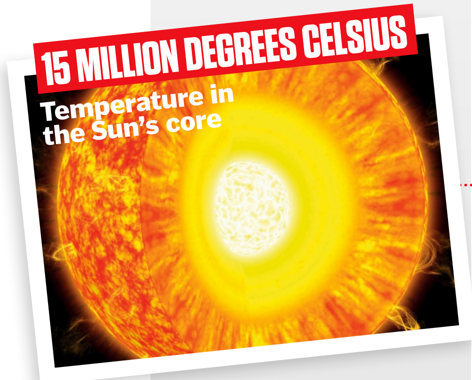
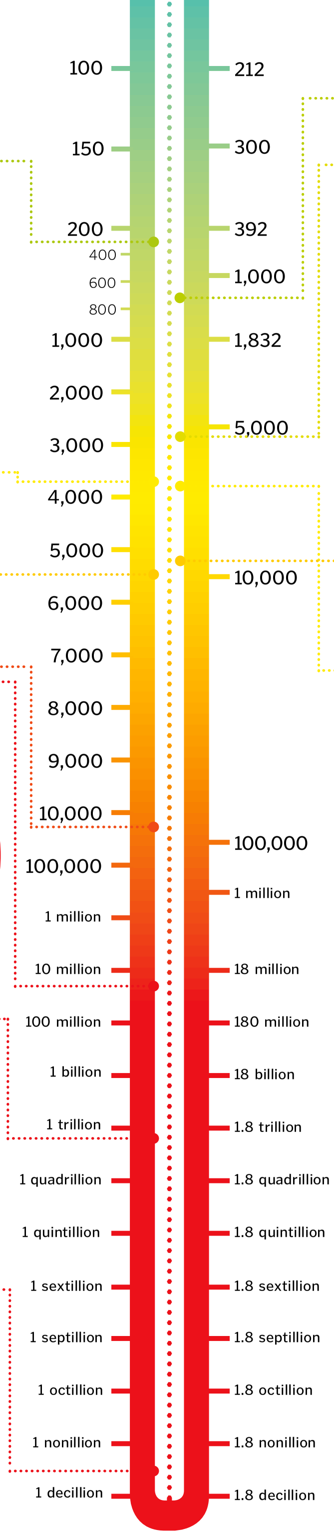


15 MILLION DEGREES CELSIUS
Temperature in the Sun's core

357°C
Mercury boiling point
The properties which give mercury the lowest melting point of all metals mean it also forms a gas at a low temperature.

3,825°C
Carbon sublimation point
Solid carbon is very stable. In Earth's atmosphere it doesn't melt, it reacts or sublimes straight to a gas instead.

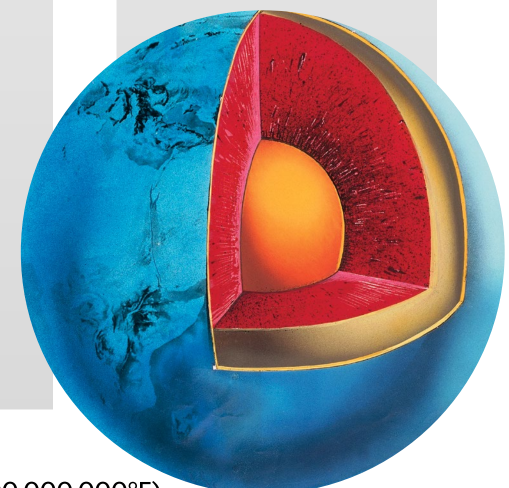


2,861°C
Iron boiling point
While it's one of the strongest materials humans use to make things, by 2,861 degrees Celsius iron has vaporised into a gas.

763°C
Diamond sublimation temperature
In Earth's atmosphere, diamonds don't vaporise into carbon gas. Instead they react with oxygen in the air to form carbon dioxide.

3,958°C
Highest temperature solid found
Researchers have found that hafnium carbide can withstand nearly 4,000 degrees Celsius, making it a potential heat shield for hypersonic space vehicles.

5,200°C
Earth's core
Our planet's centre is a hot, iron ball under high pressures, meaning it forms plasma that behaves as a solid.



5.5 TRILLION DEGREES CELSIUS
Hottest human-made temperature
Physicists at CERN's Large Hadron Collider (LHC) in Geneva, Switzerland, made the hottest temperatures humans have ever recorded. They shot beams of lead ions into a ring-shaped synchrotron, where magnetic fields speed up the ions. When two of these ions collide they release enough energy to produce a 5.5 trillion degree Celsius temperature. This is so extreme that the lead ions break down to a quark-gluon plasma, which scientists think existed near the start of the Big Bang.

142 NONILLION DEGREES CELSIUS
Planck temperature
This may be an upper temperature limit where particle energies could cause three fundamental forces to unify as just one.

Planck temperature
142,000,000,000,000,000,000,000,000,000,000°C (255,000,000,000,000,000,000,000,000,000,000°F)
The hottest theoretical temperature of matter achievable

HOW TIME WORKS

From the beginning of the universe to the present day, it's one of the few things we regard as regular and unchanging. But is it really so constant? We take a look at the physics of time…

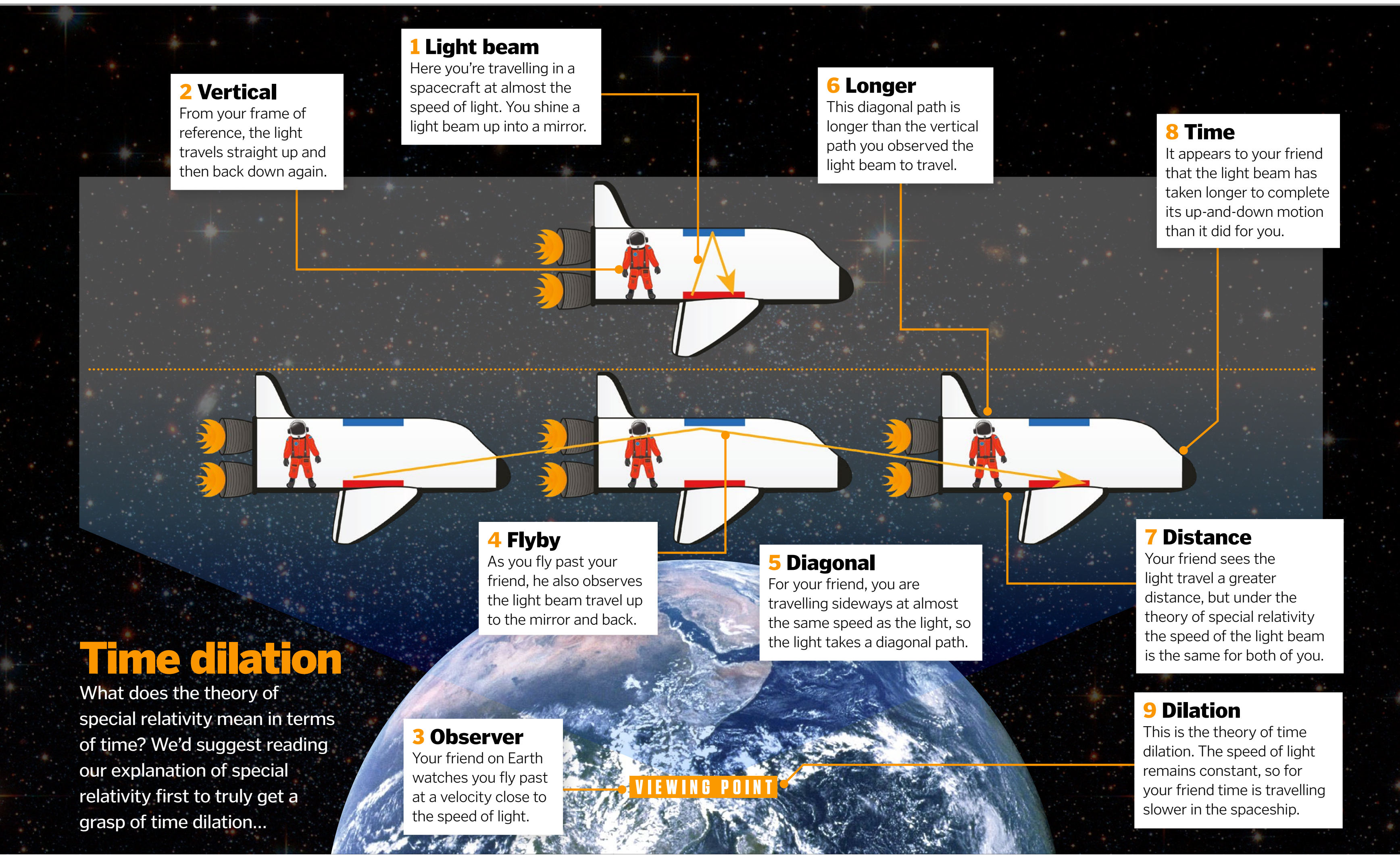
You should probably sit down to read this feature. When considering time, it's easy to quickly get lost in the complexity of the topic. Time is all around us, it's ever present and is the basis of how we record life on Earth. It's the constant that keeps the world, the Solar System and even the universe ticking.

Civilisations have risen and fallen, stars have been born and extinguished and our one method of keeping track of every event in the universe and on Earth has been comparing them to the present day with the regular passing of time. But is it really a constant? Is time really as simple as a movement from one second to the next? We're about to find out.

13.8 billion years ago the universe was born, and since then time has flown by to the present day, overseeing the creation of galaxies and the expansion of space. But when it comes to comparing time, it's daunting to realise just how little of time we've actually experienced.

The Earth might be 4.5 billion years old, but we modern humans have inhabited it for around 300,000 years, just 0.002 per cent the age of the universe. Feeling small and insignificant yet? It gets worse. You've experienced so little time on Earth that in astronomical terms you're entirely negligible. You would have to relive your life 150,000 times just to match the age of the youngest known star in the universe.

In the 17th century Newton saw time as an arrow fired from a bow, travelling in a direct, straight line and never deviating from its path. To Newton, one second on Earth was the same length of time as that same second on Mars, Jupiter or in deep space. He believed that absolute motion could not be detected, which meant that nothing in the universe had a constant speed, even light. By applying this theory he was able to assume that if the speed of light could vary, then time must be constant. Time must tick from one second to the next, with no difference between the length of any two seconds. This is something that you probably think to be true. Every day has roughly 24 hours; you don't have one day with 26 and one with 23.



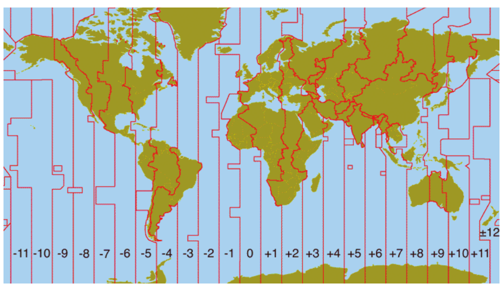
Time dilation

What does the theory of special relativity mean in terms of time? We'd suggest reading our explanation of special relativity first to truly get a grasp of time dilation…

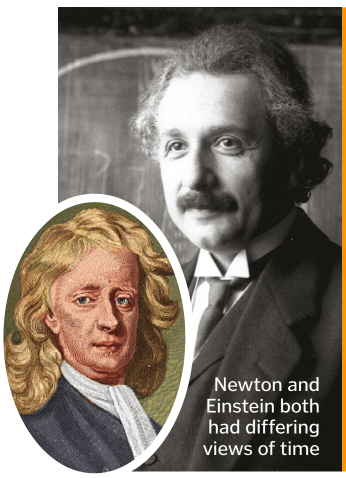
However, in 1905 Albert Einstein asserted that the speed of light doesn't vary, but rather it is a constant, travelling at roughly 299,792,458 metres per second. He postulated that time was more like a river, ebbing and flowing depending on the effects of gravity and space-time. Time would speed up and slow down around cosmological bodies with differing masses and velocities, and therefore one second on Earth was not the same length of time everywhere in the universe.

This posed a problem. If the speed of light was really a constant, then there had to be some variable that altered over large distances across the universe. With the universe expanding and planets and galaxies moving on a galactically humongous scale, something had to give to allow for these small fluctuations. And this variable had to be time.

It was ultimately Einstein's theory that was not only believed to be the truth, but also proven to be entirely accurate. In October 1971, two physicists named Hafele and Keating set about proving its validity. To do this they flew four caesium atomic clocks on planes around the world, eastwards and then westwards.



Time zones are separated by a distance of 15 degrees longitude extending from pole to pole, but for political reasons some countries and provinces have chosen to belong to a different time zone than the one in which they are geographically located



Newton and Einstein both had differing views of time

Special relativity How Einstein changed our perception of time

Einstein's theory of special relativity relies on one key fact: the speed of light is the same no matter how you look at it. To put this into practice, imagine you are travelling in a car at 20 miles per hour, and you drive past a friend who is standing still. As you pass them, you throw a ball out in front of the car at ten miles per hour.

To your friend the ball's speed combines with that of the car, and so appears to be travelling at 30 miles per hour. Relative to you, however, the ball travels at only ten miles per hour, as you are already travelling at 20 miles per hour.

Now imagine the same scenario, but this time you pass your stationary friend while travelling at half the speed of light. Through some imaginary contraption, your friend can observe you as you travel past. This time you shine a beam of light out of the car windscreen.

In our previous calculation we added together the speed of the ball and the car to find out what your friend saw, so in this instance, does your friend see the beam of light travelling at one-and-a-half times the speed of light?

According to Einstein, the answer is no. The speed of light always remains constant, and nothing can travel faster than it. On this occasion, both you and your friend observe the speed of light travelling at its universally agreed value at roughly 299,792,458 metres per second. This is the theory of special relativity, and it's very important when talking about time.

According to Einstein's theory, when compared with ground-based atomic clocks – in this instance at the US Naval Observatory in Washington DC – Hafele and Keating's airborne clocks would be about 40 nanoseconds slower after their eastward trip, and about 275 nanoseconds faster after travelling west, due to the gravitational effects of the Earth on the velocity of the planes. Incredibly, the clocks did indeed register a difference when travelling east and west around the world – about 59 nanoseconds slower and 273 nanoseconds faster respectively when compared to the US Naval Observatory. This proved that Einstein was correct, specifically with his theory of time dilation, and that time did indeed fluctuate throughout the universe.

Newton and Einstein did agree on one thing, though – that time moves forward. So far there's no evidence of anything in the universe that is able to dodge time and move forwards and backwards at will. Everything ultimately moves forward in time, be it at a regular pace or slightly warped if approaching the speed of light. Can we answer why time ticks forward, though? Not

> "Time was more like a river, ebbing and flowing depending on the effects of gravity"

quite, although there are several theories as to why it does. One of these brings in the laws of thermodynamics, specifically the second law. This states that everything in the universe wants to move from low to high entropy, or from uniformity to disorder, beginning with simplicity at the Big Bang and moving to the almost random arrangement of galaxies and their inhabitants in the present day. This is known as the 'arrow of time', coined by British astronomer Arthur Eddington in 1927.

He suggested that time was not symmetrical: "If as we follow the arrow we find more and more of the random element in the state of the world, then the arrow is pointing towards the future; if the random element decreases, the arrow points towards the past." For example, if you were to observe a star in almost uniformity, but later saw it explode as a supernova and become a scattered nebula, you would know that time had moved forward from equality to chaos.

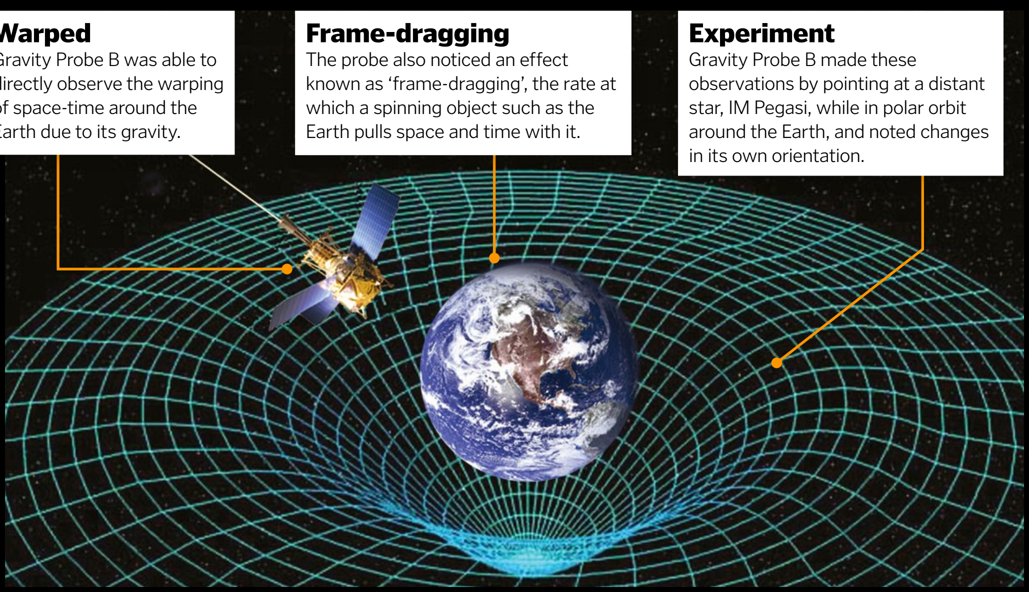
Another theory suggests that the passage of time is due to the expansion of the universe. As the universe expands it pulls time with it, as space and time are linked as one, but this would mean that if the universe were to reach a theoretical limit of expansion and begin to contract, then time would reverse, a slight paradox for scientists and astronomers. Would time really move backwards, with everything coming back to an era of simplicity and ending with a 'Big Crunch'? It's unlikely we'll be around to find out, but we can postulate on what we think might happen.

It's incredible to think of the progress we've made in our understanding of time over the past century. From ancient time-telling sundials to modern atomic clocks, we can even track the passing of a second more closely than ever before. Time remains a complex topic, but thanks to scientific visionaries, we are getting closer to unlocking the secrets of this not-so-constant universal constant.

Warped
Gravity Probe B was able to directly observe the warping of space-time around the Earth due to its gravity.

Frame-dragging
The probe also noticed an effect known as 'frame-dragging', the rate at which a spinning object such as the Earth pulls space and time with it.

Experiment
Gravity Probe B made these observations by pointing at a distant star, IM Pegasi, while in polar orbit around the Earth, and noted changes in its own orientation.



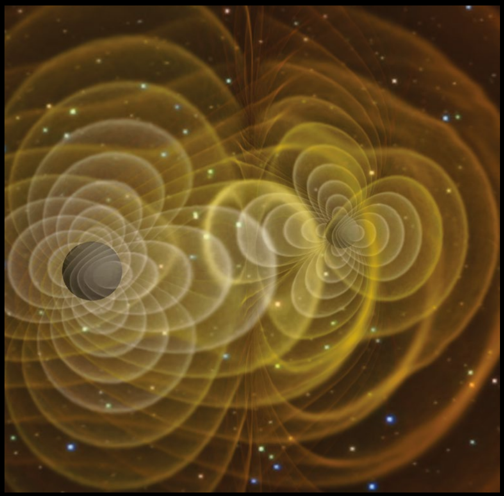
Space-time

When it was first suggested that the Earth was a sphere in three dimensions as opposed to a flat two-dimensional plane of sorts, the idea was largely scoffed at until experimental evidence proved it to be true. The same can be said with space-time, albeit with an extra dimension involved. It was once thought that space and time were separate, and that the universe was merely an assortment of cosmic bodies arranged in three dimensions. Einstein, however, introduced the concept of a fourth dimension – time – that meant that space and time were inextricably linked. The general theory of relativity suggests that space-time expands and contracts depending on the momentum and mass of nearby matter. The theory was sound, but all that was needed was proof.

That proof came courtesy of NASA's Gravity Probe B, which demonstrated that space and time were indeed linked. Four gyroscopes were pointed in the direction of a distant star, and if gravity did not have an effect on space and time, they would remain locked in the same position. However, scientists clearly observed a 'frame-dragging' effect due to the gravity of the Earth, which meant the gyroscopes were pulled very slightly out of position. This seems to prove that the fabric of space itself can be altered, and if space and time are linked, then time itself can be stretched and contracted by gravity.

© NASA

Gravity Probe B was an incredibly complex piece of machinery



© NASA

How the gravitational waves of two merging black holes would interact under Einstein's theory of general relativity

Atomic clocks

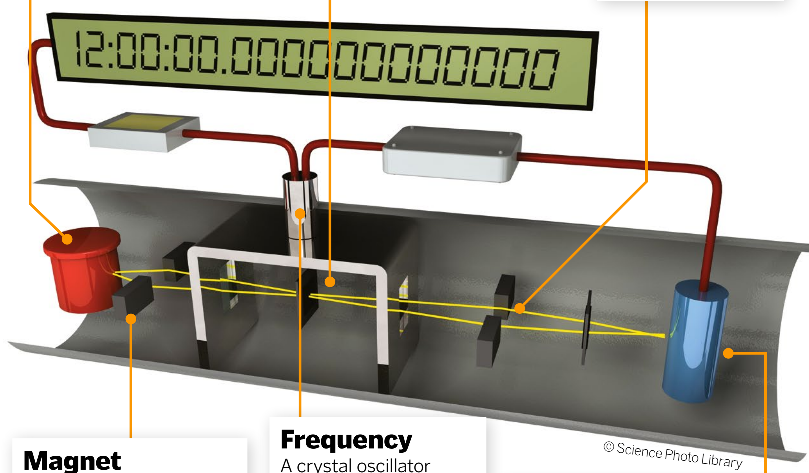
The most accurate clock in the universe would probably be a rotating star like a pulsar, but on Earth it's atomic clocks that provide the most accurate track of time. The entire GPS system in orbit around Earth uses atomic clocks to accurately track positions and relay data to Earth, while entire scientific centres are set up to calculate the most accurate measure of time, usually by measuring transitions within a caesium atom.

While most atomic clocks rely on magnetic fields, modern clocks are using lasers to track and detect energy transitions within caesium atoms and keep a more definite measure of time. Although caesium clocks are currently used to keep time around the world, strontium clocks promise twice as much accuracy, while an experimental design based on charged mercury atoms could reduce discrepancies even further to less than one second lost or gained in 400 million years.

Heated
Atoms are 'boiled' out of caesium by heating it and are subsequently sent through a tube with a high vacuum.

Microwaves
The selected atoms are passed through a microwave field of high intensity that has a fluctuating frequency.

Separation
Some atoms will change their energy state at this exact frequency, and a second magnetic field separates these out.



© Science Photo Library

Magnet
A magnetic field is able to discern between atoms of varying energy states and picks the ones that are at the right level.

Frequency
A crystal oscillator allows the microwave field to accurately reach 9,192,631,770 Hertz, the resonant frequency of a caesium atom.

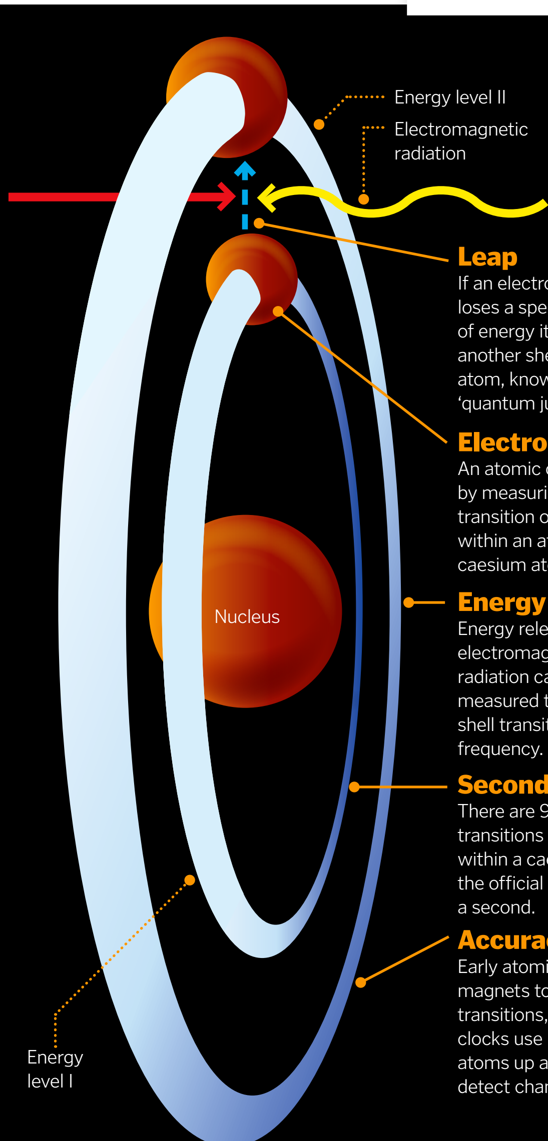
Count
A detector measures the number of atoms changing their state at this frequency. Once it detects 9,192,631,770 of these transitions, a second is said to have passed.

How long is a second?

There are two main ways of measuring time: dynamic and atomic time. The former relies on the motion of celestial bodies, including Earth, to keep track of time, whether it's the rotation time of a distant spinning star such as a pulsar, the motion of a star across our night sky or the rotation of Earth. However, a spinning star not withstanding, which can be hard to observe, these methods are not always entirely accurate.

The old definition of a second was based on the rotation of Earth. As it takes the Sun one day to rise in the east, set in the west and rise again, a day was almost arbitrarily divided into 24 hours, an hour into 60 minutes and a minute into 60 seconds. However, the Earth doesn't rotate uniformly. In fact, its rotation decreases at a rate of about 30 seconds every 10,000 years due to factors such as tidal friction. Scientists have devised ways to account for the changing speed of Earth's rotation, introducing 'leap seconds', but for the most accurate time you have to go even smaller.

Atomic time relies on the energy transition within an atom of a certain element, commonly caesium. By defining a second using the number of these transitions, time can be measured with an accuracy of losing a tiny portion of a second in a million years. The definition of a second is now defined as 9,192,631,770 transitions within a caesium atom.



Leap
If an electron gains or loses a specific amount of energy it can move to another shell within an atom, known as a 'quantum jump'.

Electron
An atomic clock works by measuring the transition of electrons within an atom, usually a caesium atom.

Energy
Energy released as electromagnetic radiation can be measured to record the shell transition frequency.

Second
There are 9,192,631,770 transitions per second within a caesium atom, the official definition of a second.

Accuracy
Early atomic clocks used magnets to track transitions, but modern clocks use lasers to push atoms up and down and detect changes.

TIME COMPARISON

How do these different lengths compare?

13.8 BILLION YEARS Age of the universe

4.5 BILLION YEARS Age of the Earth

65 MILLION YEARS Time since the extinction of the dinosaurs

365.2422 DAYS Earth's orbit around the Sun

1 SECOND Average length of a heartbeat

ONE TENTH OF A SECOND Eyes blinking

ONE HUNDREDTH OF A SECOND Lightning strike

ONE TRILLIONTH OF A BILLIONTH OF A SECOND Shortest measurable length of time

What is dandruff?

The causes of an itchy and flaky scalp

Puberty is a common time to experience dandruff as the scalp produces more oil

© Alamy

The skin on your head is constantly being replaced, but most of the time the shedding of dead skin cells goes unnoticed. It's natural for your skin to shed occasional flakes, but sometimes this process can accelerate, and you may find your head and clothes littered with a white dusting. These flakes of dry skin can be caused by dandruff, a common condition which leaves sufferers with a dry and itchy head.

Skin conditions like seborrheic dermatitis and psoriasis can cause dandruff, but one of the most common causes is a yeast-like fungus called *Malassezia globosa*. Feeding on your scalp's oil, the fungi create excess dry skin. Although dandruff sufferers may find themselves wanting to add moisture to their dry scalp, depending on the dandruff's cause, adding oil can sometimes make the situation worse by providing food for the fungi. Whether you're sick of itching, embarrassed of the constant remnants on your shoulders or just want answers, seeking assistance from a medical professional can help you understand what's causing your dry scalp and how best to relieve it.

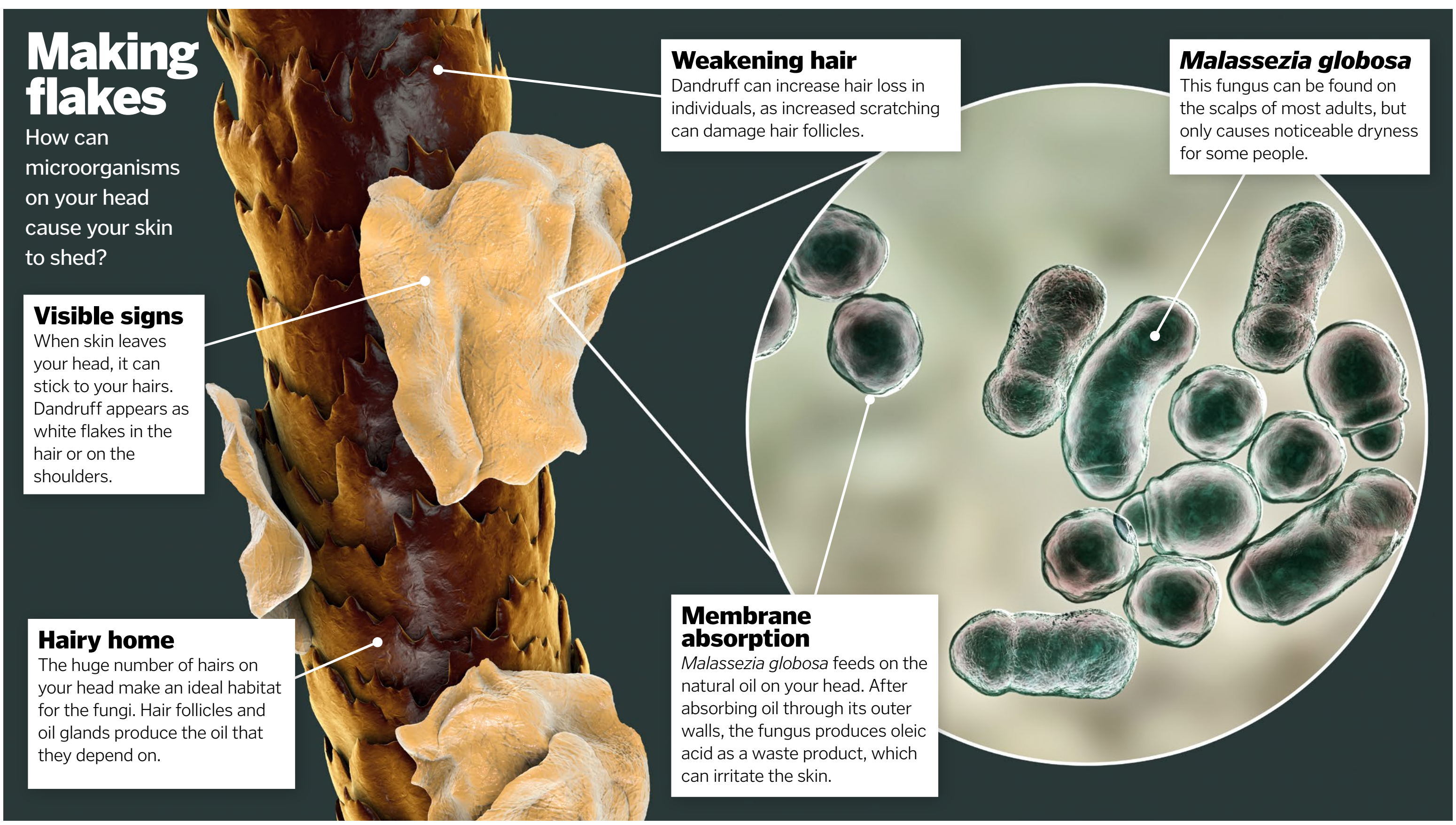
> "It's natural for skin to shed occasional flakes, but sometimes this can accelerate"

Antifungal treatment

One of the most successful and simple remedies for dandruff is a good shampoo. Antifungal shampoos are specifically designed to stop *Malassezia globosa* from growing. When used daily, it keeps oleic acid produced by the fungi to a minimum. Alternatively, doctors sometimes recommend selenium sulphide or tar-based shampoos, which reduce the speed at which your skin cells die to limit dandruff. Coal tar is classed as a keratoplastic drug, which works by shedding the top layer of skin and slowing the turnover speed of skin cells. Growing and dying at a slower speed, fewer flakes are shed.

© Alamy

The active ingredient in Head and Shoulders shampoo is the antifungal and antibacterial zinc pyrithione



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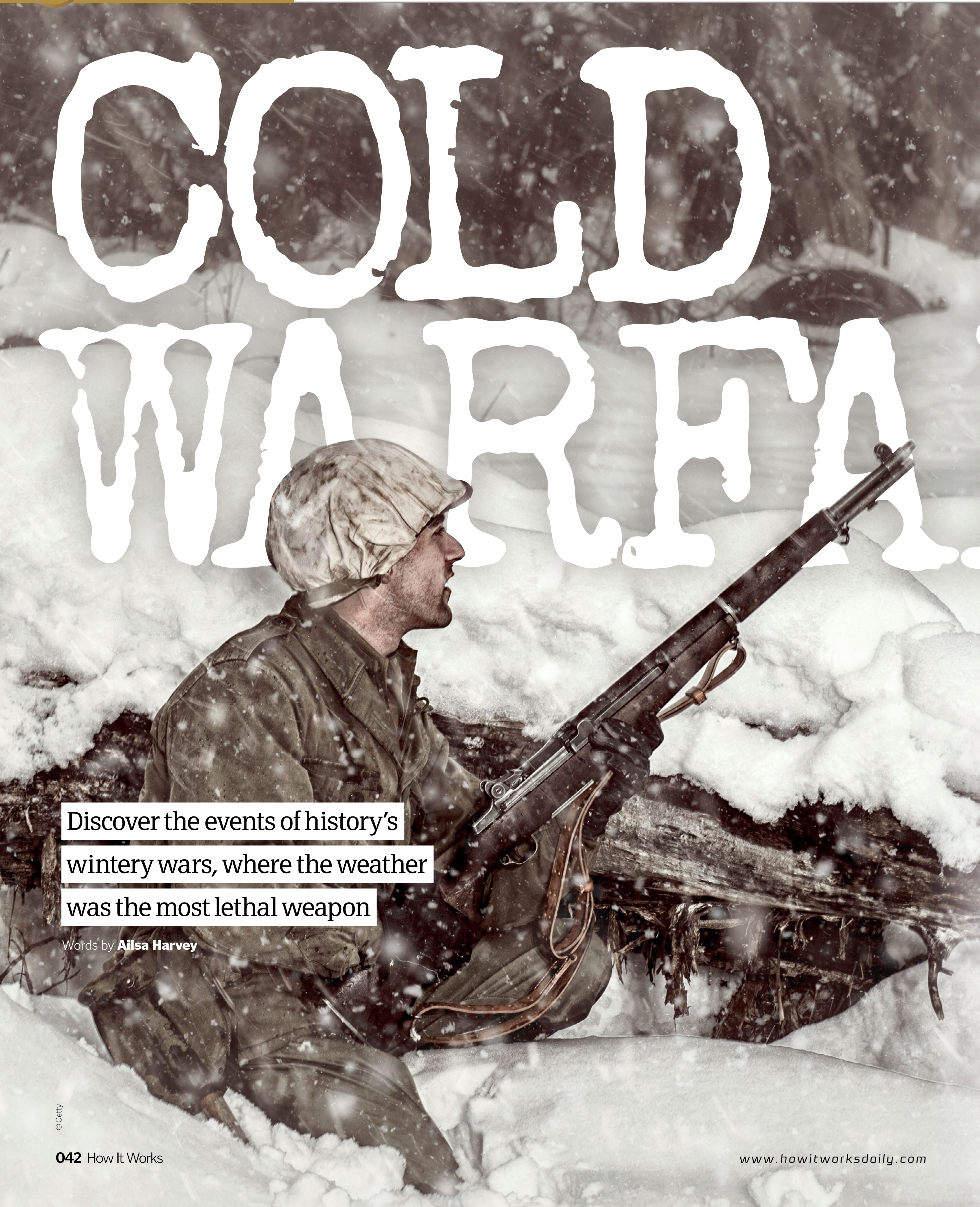


COLD WARFA

Discover the events of history's wintery wars, where the weather was the most lethal weapon

Words by **Ailsa Harvey**

RE

How do we cope when temperatures fall far below zero, mighty snowstorms sap our strength and frost-covered floors knock us from our feet with surprising ease? Just stepping outside in extreme weather can feel like a fight in itself sometimes. But how would you manage if you were forced to spend hours in these numbing conditions? Physically, the human body begins to shut down after long periods of time in very low temperatures, as our internal heat becomes compromised. In fact, if our core body temperature drops by just two degrees Celsius, we can begin to experience early signs of hypothermia.

For those who fought in some of history's coldest wars, there was no option to step back indoors. Their lives were in danger from two major threats. As their bodies were battered by the frosty conditions, they needed to retain the strength to dodge the wall of weapons being launched towards them. The only way to warmth was to eliminate the human threat before them.

As much as the cold has been a hindrance to some armies, the changing properties of frozen landscapes could sometimes be used to their advantage on the battlefield. For those fighting on their home turf, the experience of navigating icy ground allowed them to focus on the fight. In other cases, poor visibility benefited defence, like a natural smoke bomb. From the mid-storm scheming of the Middle Ages to the fight against frostbite in 20th-century warzones, these are some of history's most bitterly cold battlefields.

As Russian troops retreated, Napoleon's cannons broke the ice covering the frozen Satschan ponds, drowning soldiers
© Alamy

Freezing fog of Austerlitz

2 DECEMBER 1805 MORAVIA, AUSTRIA

In this battle of the War of the Third Coalition, French military leader Napoleon emerged triumphant. What did he do to attain this result? He incorporated the difficult weather conditions that surrounded him into his attack: instead of waiting for better visibility, he used this weather to his advantage. Amid the sub-zero fog, his tactic was to confuse the Russian and Austrian forces, whose troops outnumbered Napoleon's French army by over 20,000 men.

By pretending to retreat from the small town of Austerlitz, Napoleon made it appear that their side was weak. He planned to convince the allied Russian-Austrian armies to move into an area of dense fog. When the enemy was in place, Napoleon's troops returned to the area to attack their surprised targets, charging and reemerging from the winter fog.

This painting depicts the aftermath of the Battle of Eylau
© Alamy

The Eylau snowstorm

7 TO 8 FEBRUARY 1807 EYLAU, EAST PRUSSIA

By 1807, Napoleon was on a winning streak, but the Battle of Eylau provided a bitter end to his successes. While he was expecting another victory, he wasn't prepared for the snowstorm that encased the skirmish. In this 14-hour battle against Russia and the Prussians, the violent storm significantly reduced visibility so that his troops could only see soldiers standing immediately before them. Following a plan became difficult as every man fought for their survival.

However, surviving the fight didn't necessarily mean surviving the day. After the bloody battle, many of those wounded were left to freeze to death before they could be recovered. Temperatures continued to drop, and the attack persisted until after nightfall. When both sides were too exhausted to continue, they halted the fighting.

Battle on the Ice

5 APRIL 1242 LAKE PEIPUS, RUSSIA

If you've ever attempted to walk on a sheet of ice, you'll know how this frozen layer can upset your coordination performing even the simplest tasks. During a life-or-death contest of strength and skill, balance and perfect foot placement becomes a much more vital goal.

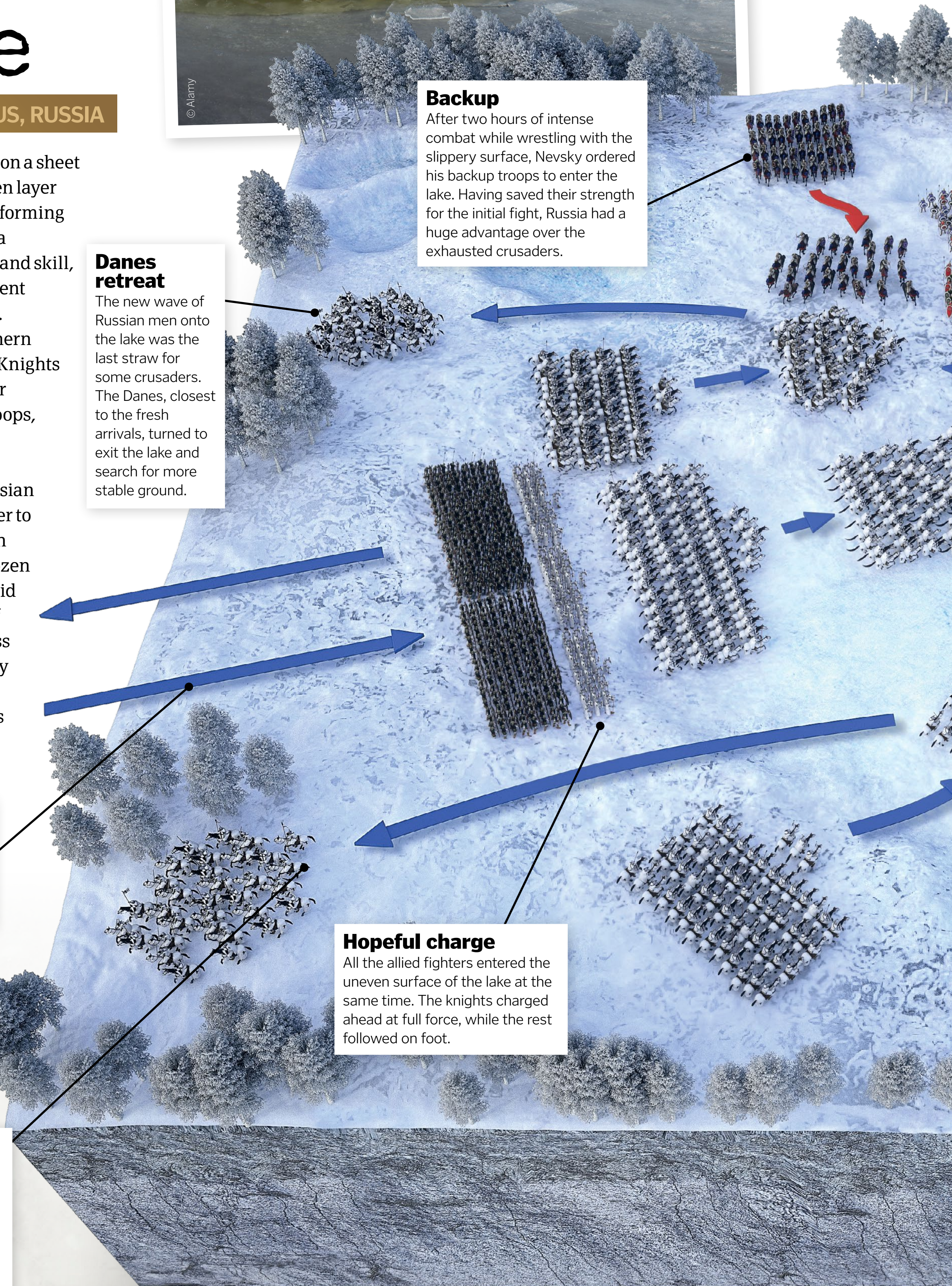
During the battles of the Northern Crusades, the German Teutonic Knights fought Russian Prince Alexander Nevsky's troops. The German troops, along with their allies, followed Catholicism and opposed the Orthodox Christian views of Russian leader Alexander Nevsky. In order to guarantee their win, the Russian soldiers led their enemy onto frozen Lake Peipus. Fighting on this solid lake required a whole new set of skills, and proved to be a ruthless test of endurance for the majority of the soldiers. The unlikely choice of battlefield is what gives the confrontation its name: the Battle on the Ice.

Lake Peipus is a large lake, covering 1,373 square miles

© Alamy

The icy strategy

How did Nevsky carry out this slippery manipulation?



Teutonic Knights enter

2,600 allied troops containing soldiers from Germany, Estonia and Denmark marched towards the frozen Lake Peipus in an attempt to catch the Russian army.

Hopeful charge

All the allied fighters entered the uneven surface of the lake at the same time. The knights charged ahead at full force, while the rest followed on foot.

Backup

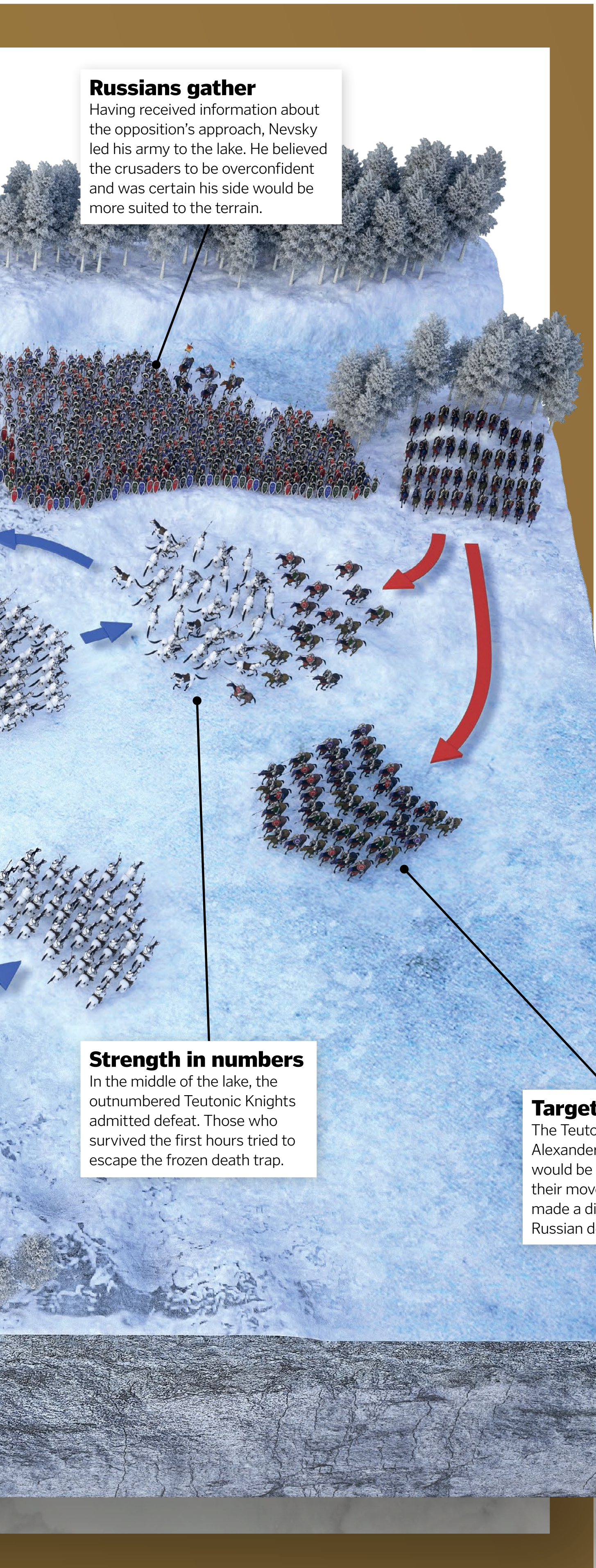
After two hours of intense combat while wrestling with the slippery surface, Nevsky ordered his backup troops to enter the lake. Having saved their strength for the initial fight, Russia had a huge advantage over the exhausted crusaders.

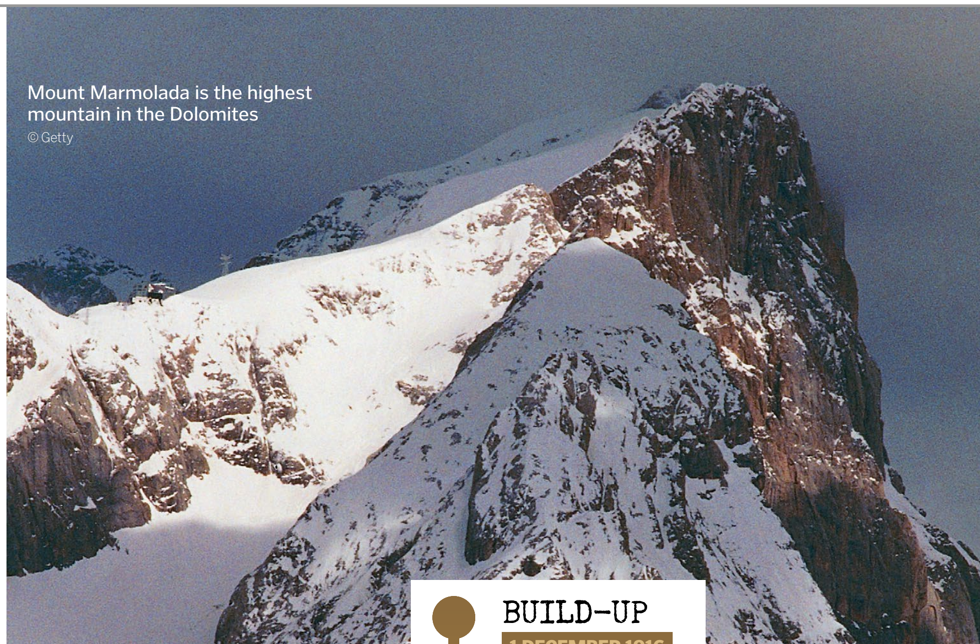
Danes retreat

The new wave of Russian men onto the lake was the last straw for some crusaders. The Danes, closest to the fresh arrivals, turned to exit the lake and search for more stable ground.

Escape the ice

Eventually, the remaining allied crusaders abandoned the lake. Nevsky's win in this battle set geopolitical boundaries that still remain today, such as across the frequently frozen lake where the Estonia-Russia border lies.




Mount Marmolada is the highest mountain in the Dolomites
© Getty

The events of 'White Friday'

MOUNT MARMOLADA, ITALY

High in the snow-packed Alps, a series of attacks took place surrounding the Austrian-Italian border during World War I. As Austria and Italy's armies climbed higher to reach better positions and continued to fire their weapons into the snowy peaks, the danger level escalated. But one particular day saw a killer with much more power than enemy fire. In mid-December 1916, a series of deadly avalanches swept away the lives of at least 2,000 soldiers.

BUILD-UP

1 DECEMBER 1916

From the beginning of the month, the summit of the mountain had gained between 8 and 12 metres of piled-up snow. Observing the accumulation, Austro-Hungarian commander Captain Rudolf Schmid demanded troops' relocation due to a potentially larger threat. His superiors, situated in the safety of their heated offices, denied this request.

OUT OF CONTACT

5 DECEMBER 1916

Eight days before White Friday, the weather caused major disruptions to telephone lines. Without communication, both sides were low on supplies and unable to contact their bases for assistance.

HEAVY SNOWFALL

6 TO 12 DECEMBER 1916

The week prior to White Friday saw persistent heavy snowfall. This only added to the build-up to a fatal avalanche.

AUSTRIA'S BARRACKS ARE BURIED

13 DECEMBER 1916 (MORNING)

At 05:30, 200,000 tonnes of snow hurtled down the slopes and filled the Austrian soldiers' barracks. Destroying everything in its path, the wooden buildings and the 332 people occupying them were instantly crushed. Only 40 bodies were recovered from the snow, and only a few survived the event, including Captain Schmid.

ITALIAN BASE BURIED

13 DECEMBER 1916 (EVENING)

Later that same day, a second avalanche erupted from the mountains above the Italian military base. This killed hundreds more, but this was not the end of the war's avalanches. These events continued throughout the rest of December, bringing casualty numbers up to their thousands.

INFLUENCING TACTICS

DECEMBER 1916

It's reported that throughout December, later avalanches were used tactically. Their destructive ability to doom large numbers was displayed in the early avalanches, so some soldiers would aim for weak spots of snow, firing their weapons to purposefully trigger avalanches above their enemies.

WWII's coldest conflicts

BATTLE OF THE BULGE

In a last major offensive towards the end of the war, Germany aimed to split up the Allied forces. Amid the icy blizzards, visibility was poor and temperatures plummeted, freezing weapons and tanks.

American soldiers during the Battle of the Bulge

© Getty

Battle of Stalingrad soldiers on the front line

© Getty

BATTLE OF STALINGRAD

Around 2 million people lost their lives as Germany attempted to take the city of Stalingrad. Becoming one of the bloodiest battles in history, the freezing temperatures added to the death toll. Most days the temperature was a harsh -20 degrees Celsius, reaching a low of -30 degrees Celsius.

LAPLAND WAR

Finland and Nazi Germany fought for power over the Lapland province during the winter, when temperatures ranged from zero to -30 degrees Celsius.

German soldier preparing weapons during the Lapland War

© Getty

Operation Silver Fox took place in Karelia, Finland

© Alamy

OPERATION SILVER FOX

The German military's main aim was to capture a Soviet port in Finland. This proved unsuccessful, largely due to the unforgiving weather. Ice and snow had frozen over most of the land, and with only a few roads available to travel, their route to the port was limited. An overall lack of preparation meant that the defence had the advantage and won.

US troops travelling across the island of Attu

© Alamy

BATTLE OF ATTU

Japan gained control of the island, getting used to the drastic difference in climate compared to their homeland. US soldiers didn't anticipate the sudden wind storms and fog-covered peaks. Early on, more American soldiers fell victim to the weather conditions, dying from frostbite and trench foot rather than from Japanese attacks.

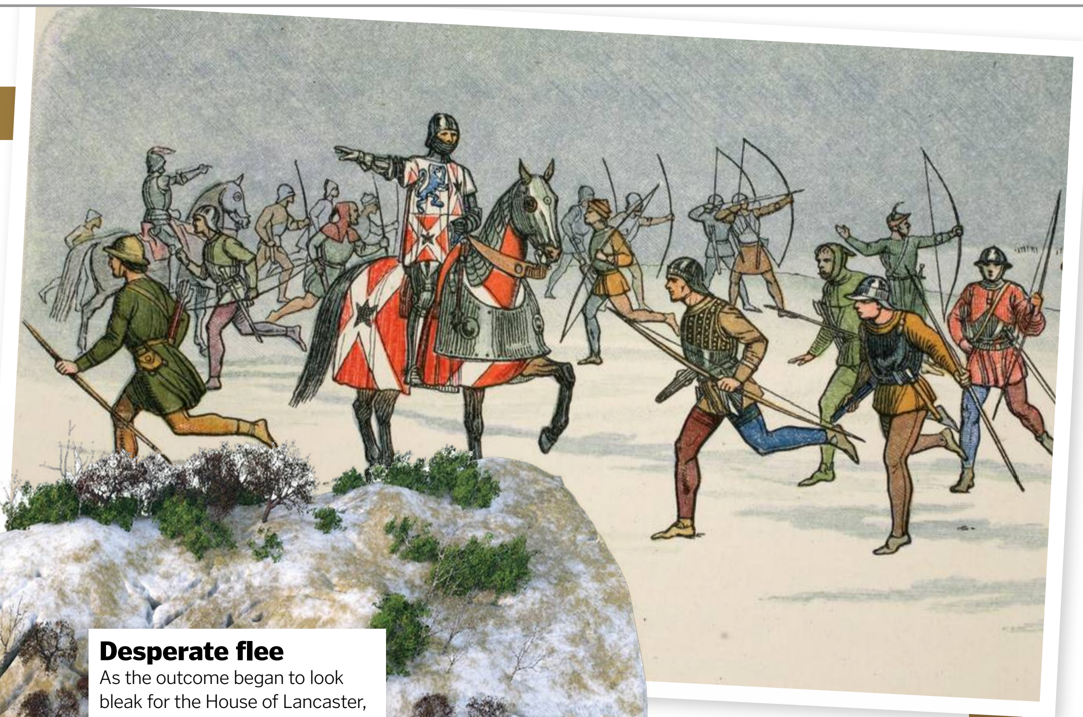
Battle of Towton: where weather was in command

29 MARCH 1461 YORKSHIRE, ENGLAND

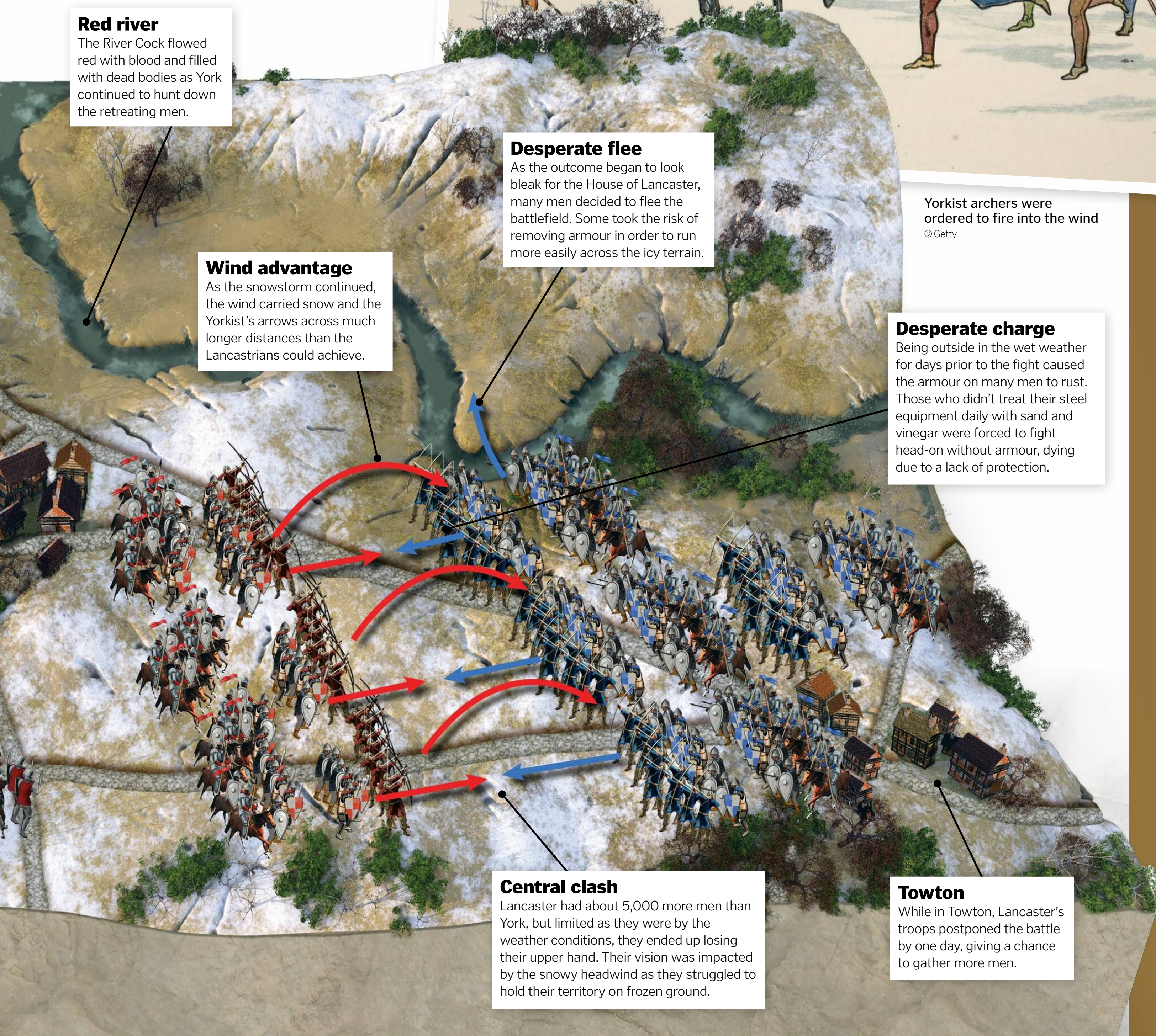
Battling the blizzard

How a relentless snowstorm impacted England's bloodiest fight

During the Wars of the Roses, multiple brutal battles were fought between the houses of York and Lancaster, with both sides eager to gain control of the English throne. The coldest of the wars' conflicts played out near the small village of Towton. Lancastrian King Henry VI denied Yorkist Edward IV his succession to the throne, and it was this argument that was to be settled in the bitter conditions of this battlefield.



Yorkist archers were ordered to fire into the wind
©Getty



HEROES OF... TRANSPORT

Yeager named many of his aircraft after his wife Glennis, including the one that broke the speed of sound

© Getty

Yeager (left) next to Major Gus Lundquist, Captain James Fitzgerald, and 'Glamorous Glennis'

© Getty

The rocket engine-powered Bell X-1 became the first aircraft to achieve supersonic flight

Source: NASA

A life's work

The journey to becoming the 'Fastest Man Alive'

1923
On 13 February, Charles Elwood "Chuck" Yeager was born in Myra, West Virginia.

1941
Yeager graduated from Hamlin High School six months before America entered World War II, joining the Army Air Corps.

Chuck Yeager

The man who made history by breaking the sound barrier

Charles "Chuck" Yeager was born in Myra, West Virginia, in 1923 – the second of five children of Albert Hal and Susie Mae Yeager. The family moved to the small town of Hamlin when Yeager was five, which at the time had only around 600 residents. Yeager's father owned a natural gas-drilling business, which meant Yeager learned all about the mechanics of generators, pumps and regulators at a young age, which transferred into his aptitude for mathematics. Yeager ended his formal education after high school and joined the Army Air Corps in 1941, only months before the attack on Pearl Harbor. He had originally joined to work on the engines of planes, but by the following year he had been selected to join the flight training program. Yeager's start in the skies wasn't smooth; some reports say he wasn't keen on leaving the ground as his first flights made him queasy. But that must have been short-lived, as by 1943 he had been awarded his pilot's wings.

Joining the fighting ranks during World War II, Yeager travelled to England as part of the Eighth Air Force to pilot a P-51 Mustang, which he named 'Glamorous Glen' after his future wife Glennis Dickhouse. He entered combat in February 1944, but on his eighth mission was shot down. He evaded enemy capture with the help of French allies and returned to England.

Yeager rejoined combat until January the following year, taking part in 61 missions, before joining the US Air Force test pilot school. After two years, Yeager had been handpicked by the chief of the Flight Test Division, Colonel Albert Boyd, to join the X-1 program. The program sought to break the sound barrier in the rocket-powered Bell XS-1 aircraft, which Yeager christened 'Glamorous Glennis'.

Having spent around a year in the program and with several high-speed test flights under his belt, it was on 14 October 1947 that Yeager achieved what no one had done before. After dropping out of the bomb bay of a Boeing B-29 Superfortress aircraft, Yeager kick-started the X-1's engines and rapidly accelerated to 0.98 Mach at around 13,100 metres in the air. Suddenly, the needle of his Machmeter swung off the scale, and a roaring sonic boom dominated the airwaves. The deafening sound signalled that Yeager had reached over Mach 1, around 700 miles per hour, and was flying quicker than the speed of sound.

Following his sound barrier-breaking success, Yeager continued as a test pilot and even acted as an adviser to the Pakistan Air Force before he retired from the US Air Force in 1975, leaving under the rank of brigadier general.

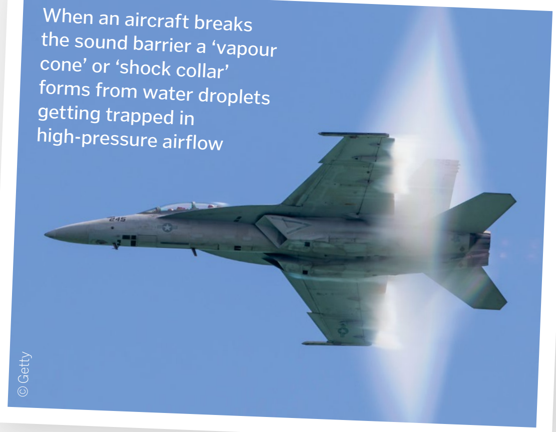
> *"Yeager had been handpicked to join the X-1 program"*

THE BIG IDEA

Breaking barriers

The speed of sound, which we refer to as Mach 1, is approximately 770 miles per hour at sea level, and an object approaching this speed will experience a sudden increase in aerodynamic drag caused by the 'sound barrier'. This phenomenon occurs because of the compressed air, sound waves and forces such as drag generated by the fast-moving object.

The sound barrier had been broken by human-made objects hundreds of years before Yeager set foot in the cockpit of a plane – bullets and cannons – and by whips thousands of years before that. What makes Yeager's achievement so monumental is that he showed the human body could withstand the forces when travelling at speeds faster than sound. This achievement ultimately paved the way for space travel and the creation of the US space program.


When an aircraft breaks the sound barrier a 'vapour cone' or 'shock collar' forms from water droplets getting trapped in high-pressure airflow

FIVE THINGS TO KNOW ABOUT... CHUCK YEAGER

1 Silver screen
Author Tom Wolfe wrote Yeager into his 1979 novel *The Right Stuff* and subsequent film of the same name, which explored the early days of the Space Race.

2 Sharpshooter
During World War II, it's reported that Yeager shot down 13 enemy planes – five in a single day.

3 Overachiever
In 1953 he surpassed his groundbreaking achievement by travelling at more than double the speed of sound, Mach 2.44 (1,650 miles per hour).

4 Delayed announcement
It wasn't until June 1948, roughly eight months after the fact, that Yeager's achievement was revealed to the world. He was quickly branded the 'Fastest Man Alive'.

5 He did it with broken ribs
Days before his historic flight, Yeager fell off a horse and broke two of his ribs. Because of the pain he had to use a sawn-off broomstick inside the cockpit to shut the plane's canopy.

1943
On 10 March he earned his wings at Luke Field, Arizona.

1947
In August, his first rocket-powered flight reached Mach 0.85.

1947
In October, he broke the sound barrier in the Bell X-1 aircraft.

1949
He became the first American to takeoff in a rocket-powered aircraft from the ground.

1958
Yeager became commander of the 1st Fighter Squadron, flying the new North American F-100D Super Sabre.

1966
He assumed command of the 405th Fighter Wing at Clark Air Base, the Philippines, where he flew 127 missions in South Vietnam.

1976
Yeager was awarded the Special Congressional Silver Medal for bravery.

2020
On 7 December, Yeager passed away aged 97.

INSIDE THE TOXIC C

Words by **Scott Dutfield**

How does city-wide smog form, and what damage can it cause?

CLOUD

Air pollution is one of the most pressing environmental issues in decades, with the World Health Organization estimating that it contributes towards around 7 million premature deaths worldwide each year. Burning fossil fuels, car emissions and agricultural activity are some of the biggest culprits in polluting our air. This pollution is typically measured and presented as a particulate matter 2.5 ($PM_{2.5}$) value. This is the size of fine particulate matter in the air that measures up to 2.5 microns in size. The higher the $PM_{2.5}$ value, the worse the air quality is in a city or country. The build-up of these $PM_{2.5}$ particulates can result in one of two types of dense smog, the most common of which is known as industrial smog.

This brownish fog is created when egg-scented sulphur and particulate-filled soot are pumped into the air from the burning of fossil fuels, combining with the water content of naturally occurring fog. Natural fog is created when moist air is cooled to a temperature that saturates it with water vapour, known as the dew point. The water vapour collects as water droplets, which disperse light and make the air hard to see through. On its own fog is non-toxic and is a very common occurrence in our environment, but when you mix in some pollution it becomes more opaque, and a health hazard.

The Great Smog

On 5 December 1952, the metropolis of London was engulfed in clouds of yellowish-brown. At the time it was common in London for the fog to mix with the smoke made by those that lived there. But on this day, a particularly dense smog reached toxic levels. Referred to as a 'pea-souper', it engulfed London for four days, stopping anyone from seeing more than a metre in front of them. It's thought that a weather phenomenon known as an anticyclone was hanging over London, pushing the air and smog to the ground and preventing it from dispersing. The smog continued to collect pollution from the capital's factories and homes. Each day around 1,000 tonnes of smoke particles were emitted, and around 2,000 tonnes of carbon dioxide. Sadly, up to 12,000 Londoners died as a result of the fog, but it led to the Clean Air Act of 1956, which sought to reduce polluting emissions from chimneys.

The 'pea-souper' engulfs Piccadilly Circus, London, on 6 December 1952

© Getty

Source: Wiki © Tomskyhaha

This is Fanhe Town in Tieling, China. These images were taken ten days apart during a passing smog cloud and after it had dispersed

The second type of smog is called photochemical smog and is equally as vision-impairing,created by a combination of human activity and sunlight. The gases emitted from cars and industry react with energy from sunlight, which produces ground-level ozone.

Around ten miles above the Earth's surface in the stratosphere, a layer of ozone creates a gaseous barrier between our planet's surface and the Sun. Its role is to block and reflect the majority of ultraviolet light emitted from the Sun, preventing it from reaching the surface. However, that's where its benefits start and end. Close contact with this gas can cause serious health issues in humans, such as lung tissue damage, irritating the skin and causing respiratory issues such as asthma.

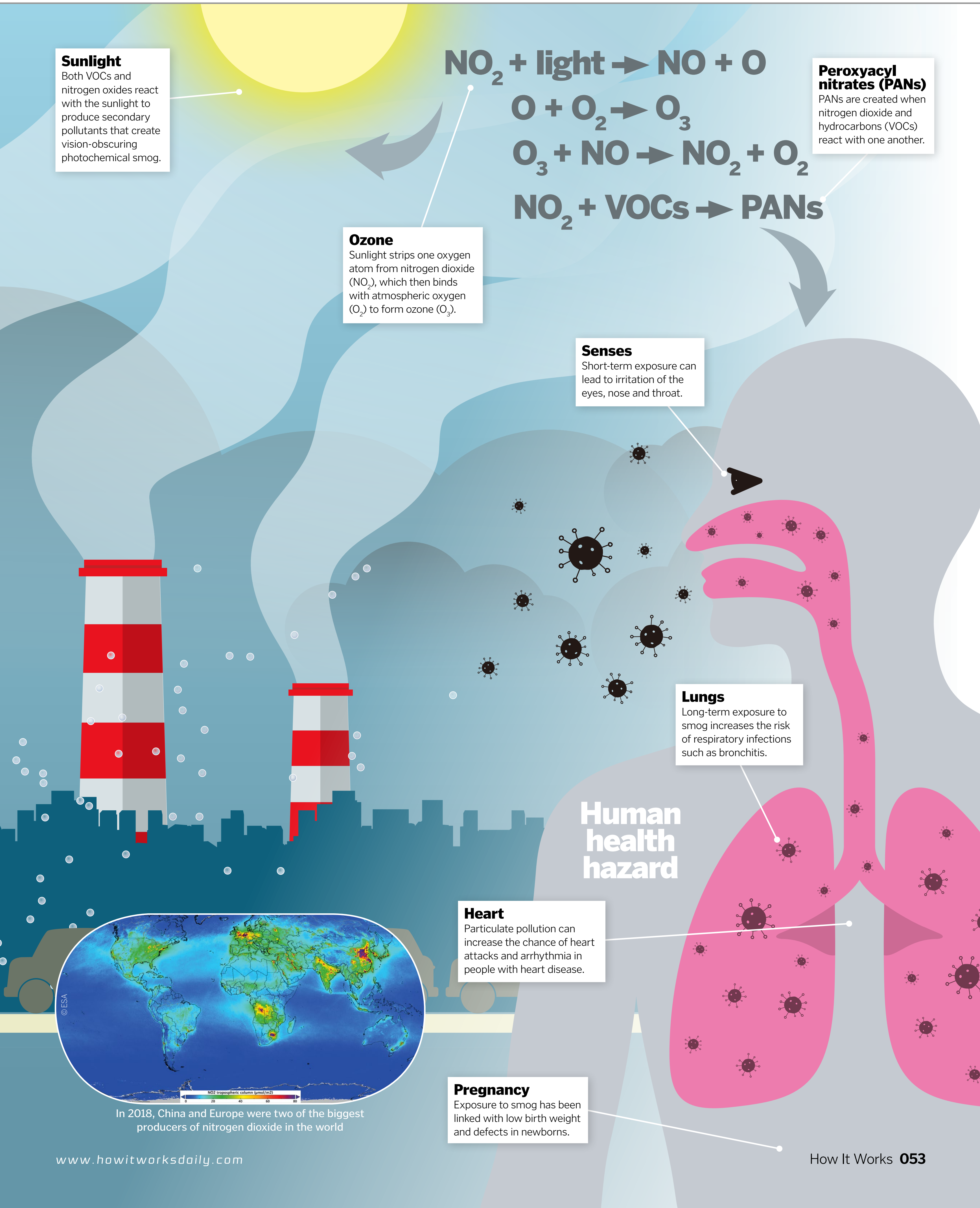
Topography and weather can also play a substantial role in the prevalence of smog. For example, if a city that is susceptible to photochemical smog, such as Los Angeles, is surrounded by a mountain range, the smog has nowhere to disperse and can become trapped by a process known as a temperature inversion. In surrounded sites with low winds the polluted

> "Close contact with this gas can cause serious health issues in humans"

warm air rises, but is trapped by a slightly warmer layer of air above it. Almost like an air net, this stops the smog from rising and dispersing until stronger, cooler winds can disrupt the inversion and free the smog.

To clean up smog, many cities and countries have put legislation in place that restricts the pollutants that contribute to smog production. However, the biggest contributor to photochemical smog, nitrogen dioxide (NO_2), continues to pollute urban air – at least it was until a global pandemic swept the world.

Cars are one of the biggest offenders in smog production, so during a time when a large portion of the planet's population is staying indoors and roads are far less congested, global air quality is getting better. According to NASA researchers, since the start of the pandemic in February 2020 there has been a 20 per cent decrease in global nitrogen dioxide concentrations. This has resulted in less smog and clearer, cleaner skies. When lockdown measures ease and people return to their cars, nitrogen dioxide levels will rise, and smog will again flow through the air. However, the pandemic has allowed us to see the effects of modern civilisation on air pollution. Hopefully this will promote efforts to tackle it in the future.



$$NO_2 + \text{light} \rightarrow NO + O$$

$$O + O_2 \rightarrow O_3$$

$$O_3 + NO \rightarrow NO_2 + O_2$$

$$NO_2 + \text{VOCs} \rightarrow \text{PANs}$$

Sunlight
Both VOCs and nitrogen oxides react with the sunlight to produce secondary pollutants that create vision-obscuring photochemical smog.

Peroxyacyl nitrates (PANs)
PANs are created when nitrogen dioxide and hydrocarbons (VOCs) react with one another.

Ozone
Sunlight strips one oxygen atom from nitrogen dioxide (NO_2), which then binds with atmospheric oxygen (O_2) to form ozone (O_3).

Senses
Short-term exposure can lead to irritation of the eyes, nose and throat.

Lungs
Long-term exposure to smog increases the risk of respiratory infections such as bronchitis.

Human health hazard

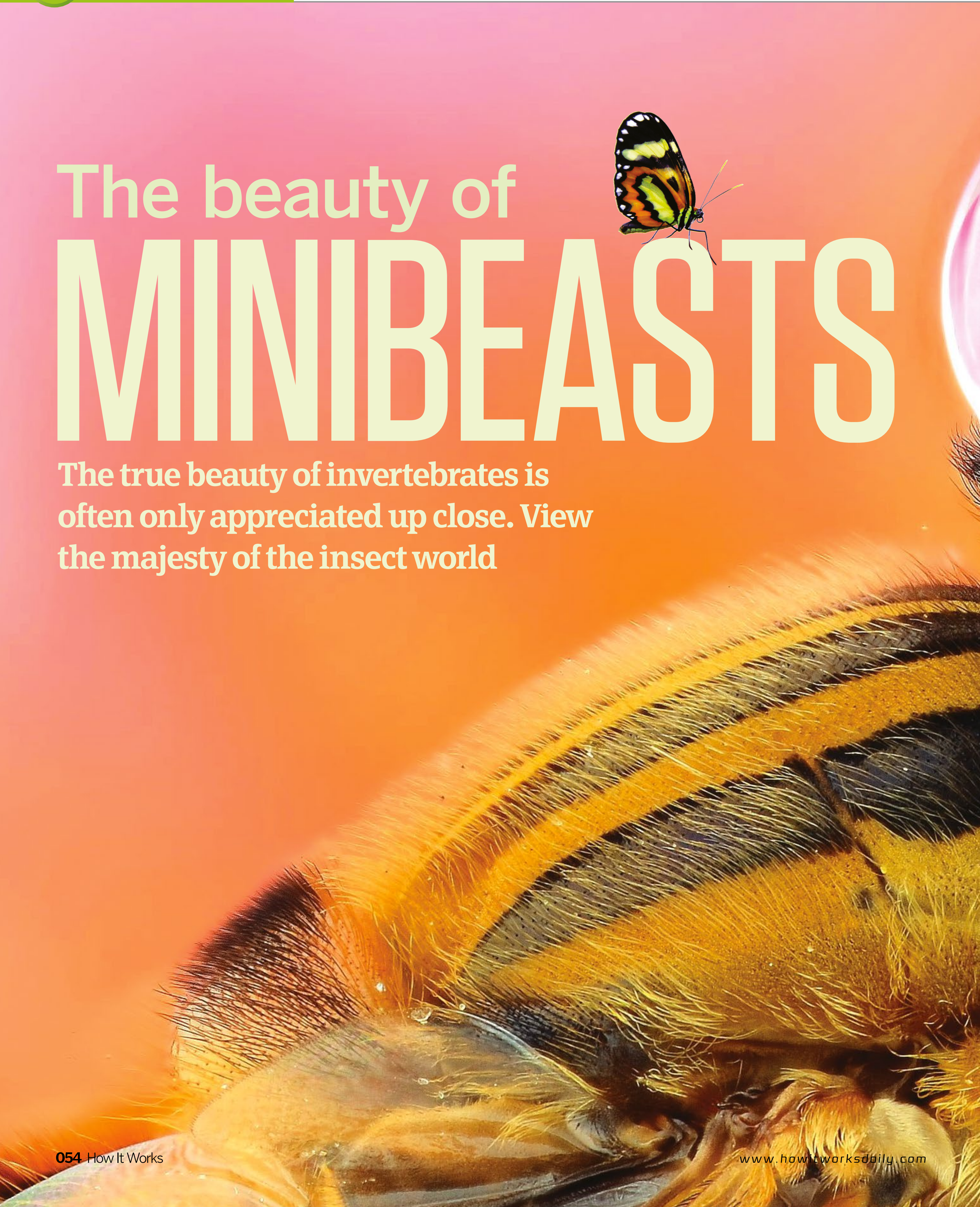
Heart
Particulate pollution can increase the chance of heart attacks and arrhythmia in people with heart disease.

Pregnancy
Exposure to smog has been linked with low birth weight and defects in newborns.

In 2018, China and Europe were two of the biggest producers of nitrogen dioxide in the world

The beauty of MINIBEASTS

The true beauty of invertebrates is often only appreciated up close. View the majesty of the insect world



Spotted-eye hoverfly

This species of hoverfly has evolved to mimic bees and wasps to avoid predators, and even copies the stinging action of wasps. This large hoverfly has one set of wings where most bees and wasps have two sets fused together. These flies are the masters of hovering, which involves extremely rapid wing movement while keeping the head perfectly level. The hoverfly's important role in the ecosystem is to help pollinate trees and shrubs.

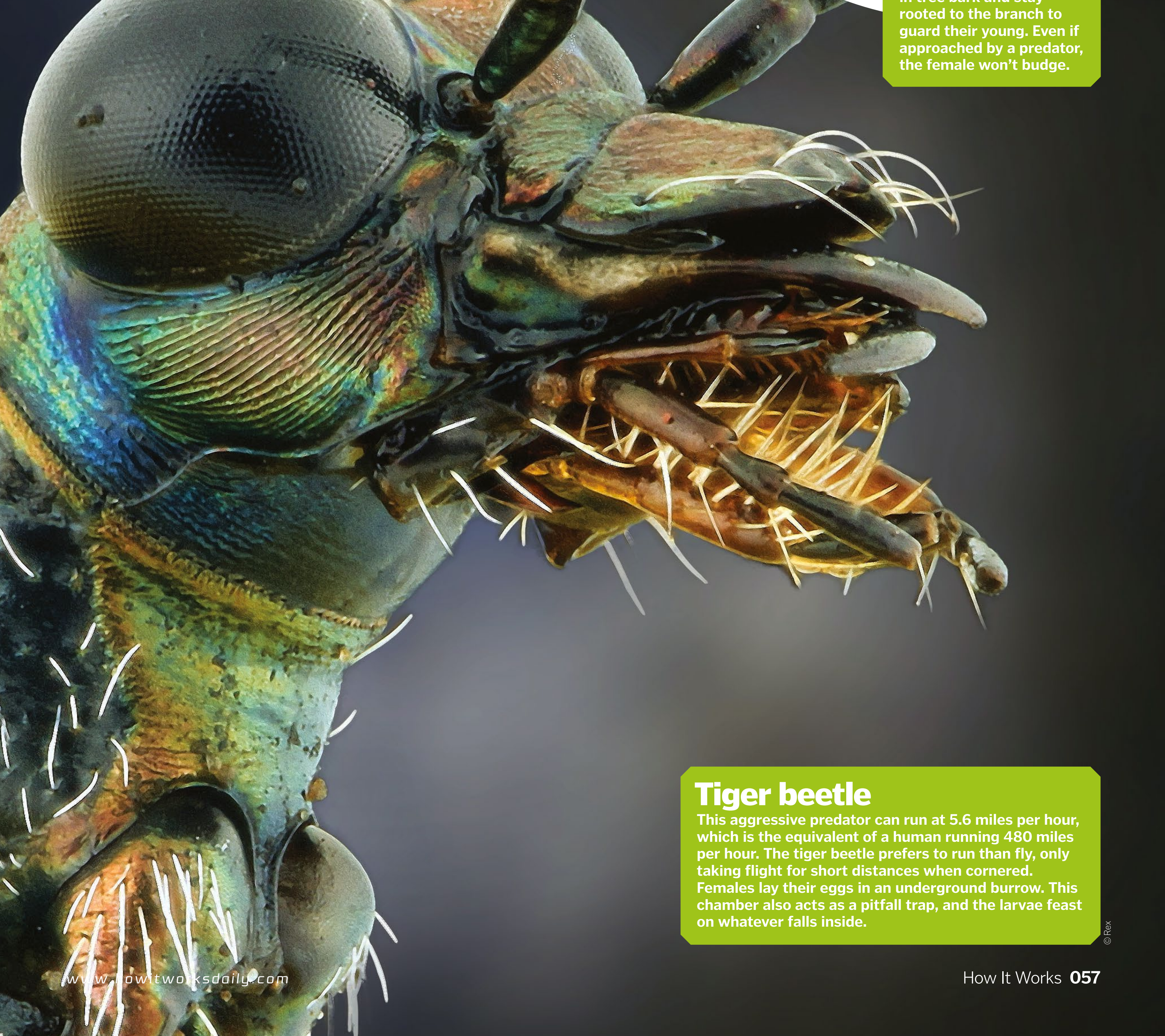
© Rex

Golden-ringed dragonfly

This agile flier is the golden-ringed dragonfly, and it can skilfully change direction mid-flight. Dragonfly wings move out of sync with each other, and each wing is controlled independently. These insects begin life in water, buried in the sediment, before morphing into their adult form. In both stages they are fierce predators. Dragonflies live from six months to six years depending on their size, and there are thousands of dragonfly species.

Thorn bug

The thorn bug is one of the best mothers in the animal kingdom. Females lay eggs in tree bark and stay rooted to the branch to guard their young. Even if approached by a predator, the female won't budge.



Tiger beetle

This aggressive predator can run at 5.6 miles per hour, which is the equivalent of a human running 480 miles per hour. The tiger beetle prefers to run than fly, only taking flight for short distances when cornered. Females lay their eggs in an underground burrow. This chamber also acts as a pitfall trap, and the larvae feast on whatever falls inside.

Oriental fruit fly

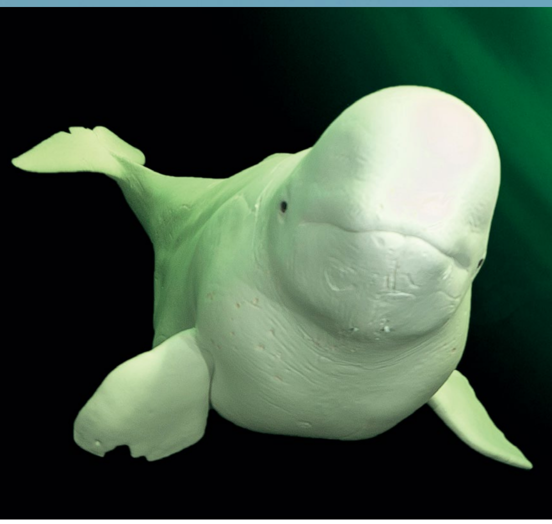
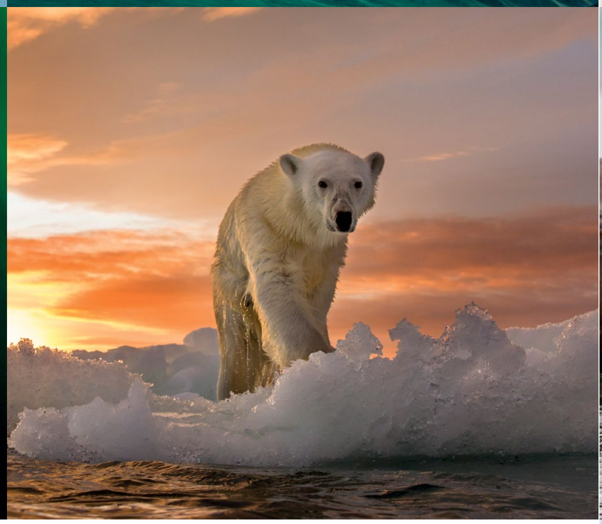
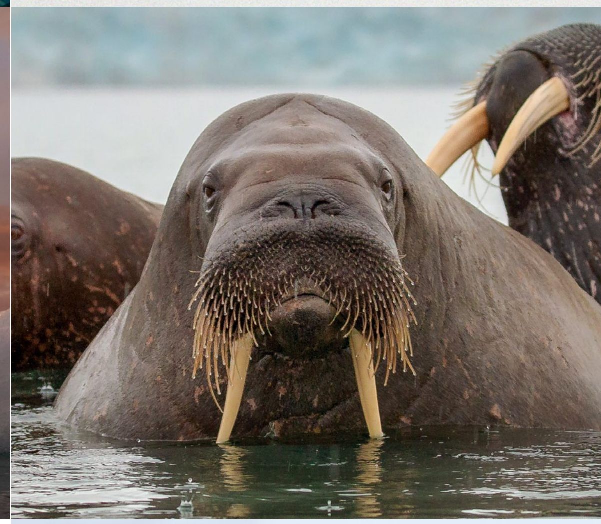
Named after their favourite foods, oriental fruit flies can lay 1,000 eggs inside fruit skins during their 90-day life span. When the maggots hatch, they burrow into the fruit to feed on pulp before dropping to the floor. The maggots then bury themselves in the soil to pupate for 10 to 12 days before emerging as an adult, becoming sexually mature seven to 14 days later.

© Rex

Gaudy grasshopper

The gaudy grasshopper's vibrant colours warn predators about its vile taste. This insect relies so much on its colouration that it rarely flies away when predators advance. This grasshopper has five eyes and no ears, but hears with an organ called the tympanum. These are layers of stretched skin like the surface of a drum that respond to air vibrations.



ANIMALS OF THE ARCTIC WILDERNESS

Explore a strange frozen world and meet the wide variety of life that calls it home

The Arctic is about as alien an environment as any non-native human will encounter on Earth. At the North Pole, days and nights last for six months at a time, temperatures can plunge to below -50 degrees Celsius and there's no land for hundreds of miles. Instead it's sheer white as far as the eye can see as a 5.4-million-square-mile sheet of thick ice stops you from getting your feet wet in a perpetually ice-capped Arctic Ocean that's never warmer than -2 degrees Celsius.

The skies often ripple and literally hum with the iridescence of the aurora borealis – surreal waves of light caused by high-energy particles colliding with our atmosphere – Sun haloes and mirages. Meanwhile, even weirder acoustic phenomena can be caused by the cold, dense air and hard ice, allowing conversations or otherwise inaudible sounds to be heard up to 1.9 miles away.

But along the continental landmasses that nudge above the geographical Arctic Circle and across the sea ice, a huge variety of highly specialised plants and animals call this harsh region of the world home. They thrive here in a carefully balanced, interdependent ecosystem where the classic food chain hierarchy isn't as transparent as it seems.


What is permafrost?

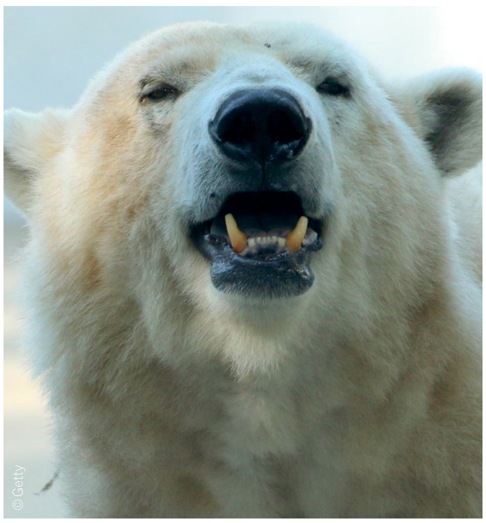
Much of the subsurface soil of Greenland, Svalbard and the northerly regions of Scandinavia, Russia, Alaska and Canada has been frozen since the last ice age. Continuous freezing and thawing in the top 20 centimetres, known as cryoturbation, allows meltwater to circulate and keep the soil relatively fertile. But lower layers than this remain permanently a few degrees below freezing, which can dramatically affect the landscape. Here, drainage is very poor, resulting in boggy ground dominated by mosses, small hills called pingos pushed up by the ice and deep cracks where water can collect and freeze. Arctic areas with little permafrost, especially southerly forest tundra regions, are host to thick shrub tundra, willows, dwarf birch and other hardy plants.

Seasonal wear

It's not just the landscape that sees a dramatic change between winter and summer. A range of creatures react to the melting snow by shedding their thick white coats and adopting black, brown or dappled coats that, along with thinner fur, can make them look like an entirely different species.

Roebuck deer turn from a ruddy fox colour in the summer to grey with white on their hindquarters in order to lose potential predators in the snow. Lemmings and Arctic hares, meanwhile, turn from dark to white in winter, also to camouflage themselves from predators. Arctic foxes and weasels have adopted this strategy too, as much an aid to hunting their own quarry as to protecting themselves. Experiments have shown that the shedding of an old coat and growing a thicker one is triggered by temperature change rather than the seasons, so the animal can change coats at the perfect time.

An Arctic fox during winter (above) and summer (right)

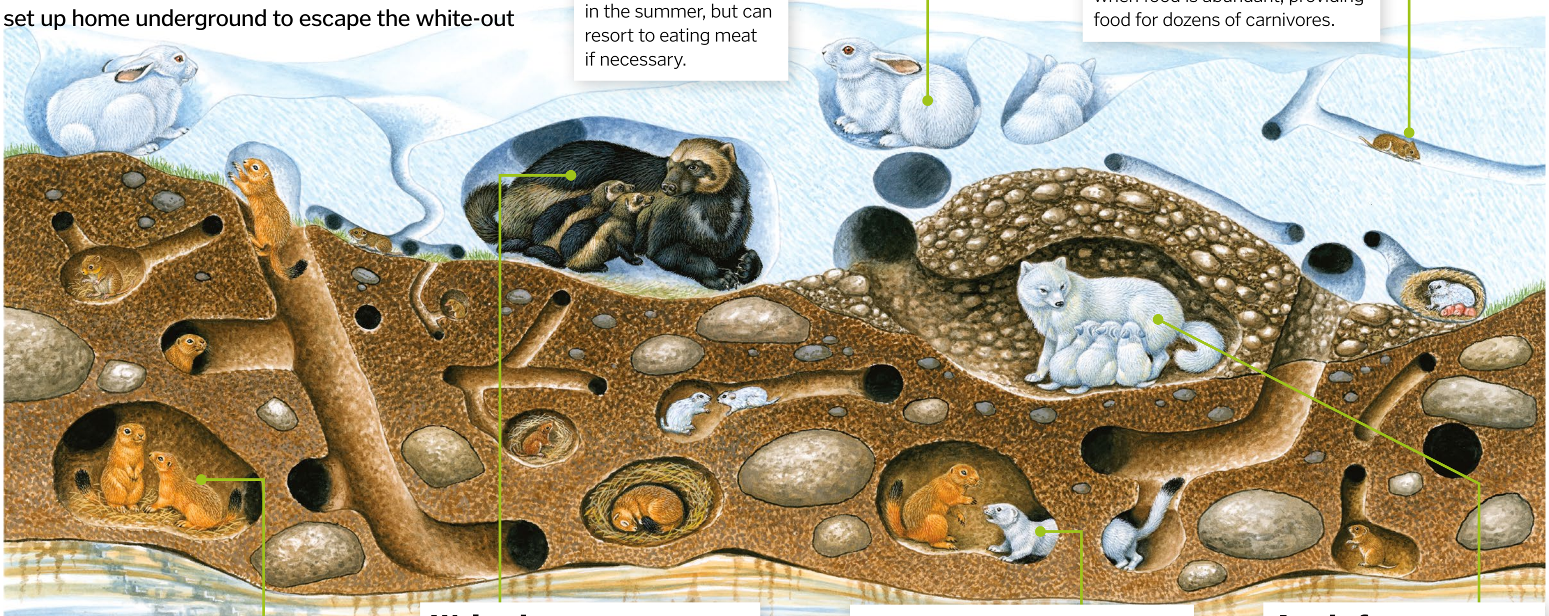


Polar predator

The polar bear is the world's biggest land carnivore – along with the Kodiak bear – and an adult male can weigh up to 800 kilograms. They're an intelligent species with an appetite for meat that's only rivalled by their insatiable curiosity. Like most bears, they have a highly developed sense of smell, capable of detecting a seal's breath from beneath thick ice. They will scavenge in bins and are opportunists with an extremely varied diet – including eating people, given the chance. Polar bears are the only species of bear that will actively hunt humans for food, though with the right precautions they are easily deterred. These bears are at far greater risk from human hunters, despite global bans.

Life beneath the snow

How It Works digs deep to reveal the critters who set up home underground to escape the white-out



Arctic hare
This species will forage for sprouts and berries in the summer, but can resort to eating meat if necessary.

Lemming
Lemmings multiply exponentially when food is abundant, providing food for dozens of carnivores.

Arctic ground squirrel
One of the few Arctic species to hibernate, it gorges during autumn and then retreats underground in winter.

Wolverine
The biggest member of the weasel family is notoriously ferocious, tackling prey like deer and sheep, and even seeing off wolves and polar bears.

Least weasel
This small and successful carnivore has a huge range that covers large parts of North America, Europe, Russia, parts of Asia and even Morocco.

Arctic fox
Like Arctic wolves, Arctic foxes have extreme northerly territories and can have as many as 25 kits in a single litter.

At the apex is the polar bear, whose blubbery prey in the form of seals, walruses and even whales become trickier to catch in the summer when the ice retreats. In this lean season, everything edible becomes fair game for the world's largest land-dwelling meat eater, including birds, berries and seaweed. Filling out the predator niches below the polar bear are smaller carnivores like the Arctic fox, snowy owl and wolverine, which will all scavenge on leftovers as well as hunt their own food. In fact, despite running the risk of becoming an entrée itself, the crafty Arctic fox will often follow polar bears in the hope of a free meal.

Lemmings are incredibly important to the whole ecosystem. Their population fluctuates from low to enormously high in a regular cycle: at their peak, as well as directly feeding the upper echelons of predators in the food chain – which time the rearing of larger broods of young to this abundance of food – they strip the summer tundra of seeds and grasses. The proliferation of their faeces is devoured by invertebrates, bacteria and fungi, as well as fertilising the soil for the next generation of flora. As a result, summer brings swarms of insect prey for insectivores like larks and waders, which in turn feed owls, falcons and other avian predators. When the lemmings can no longer sustain their numbers, the population crashes as predation and disease take over, and the land can recover.

The climate is typically cold and dark, with long, freezing winters and short, cool summers. The range of temperatures in the Arctic Circle is huge compared to elsewhere in the world, from bitter winters that average -40 degrees Celsius to hot summer highs of 30 degrees Celsius or more in some places. It is getting warmer though: the summer of 2012 saw unprecedented melting of the Arctic ice cap, with less than 50 per cent of the average summer ice coverage from 1979 to 2000. Some scientists predict that by 2050 the Arctic ice will melt completely in the summer months. The repercussions this could have go without saying, although we shouldn't jump the gun. These records only go as far back as 1979, so any doomsday predictions should definitely be put on ice for the time being.

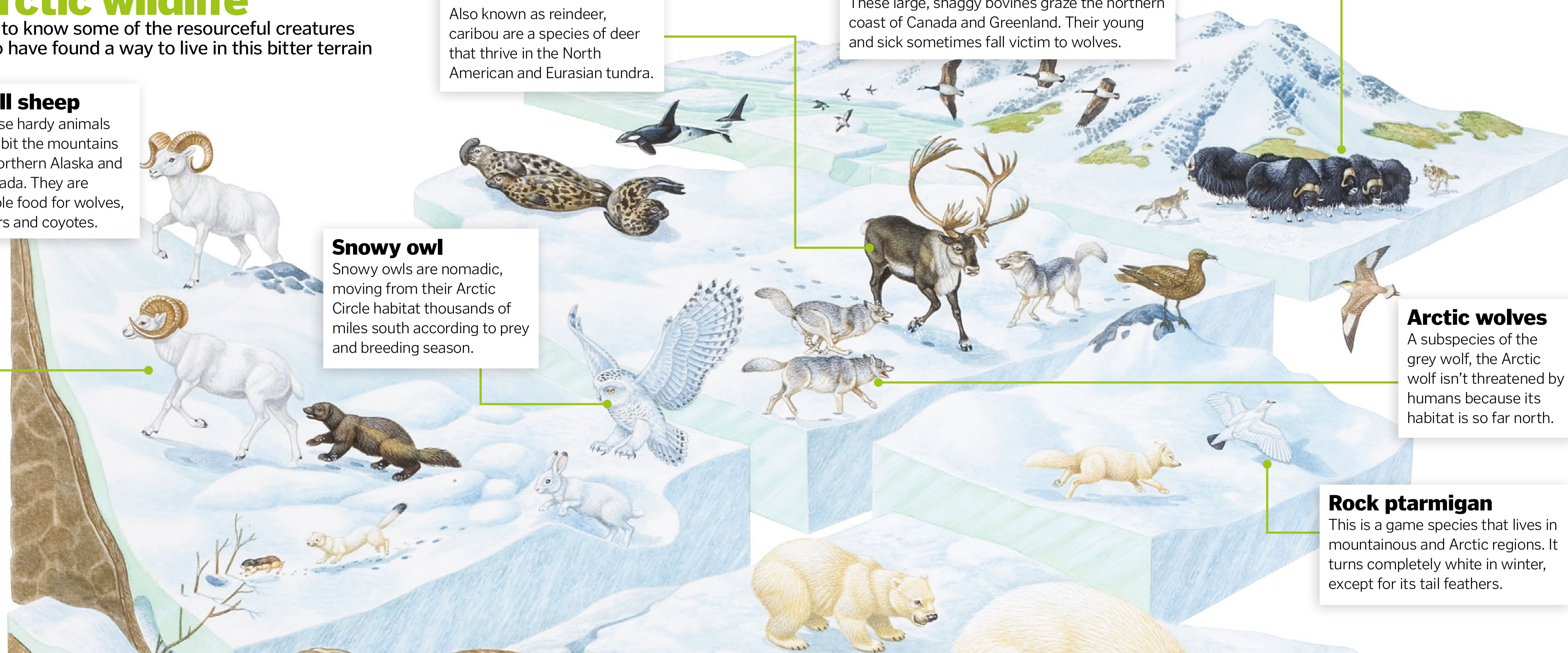

A long-exposure composite showing the movement of the Sun across the North Pole

Land of the midnight Sun

The Arctic Circle region experiences one of its most famous phenomena over a period during the summer months: the midnight Sun. The number of days the Sun can be seen in the sky at its lowest point after midnight increases the closer to the North Pole you get. At the pole itself the Sun can light up the sky for six months of the year, dipping behind the horizon for another six months and plunging the land into perpetual darkness in the winter. On the Arctic Circle border, at 66 degrees latitude, midnight Sun occurs from 12 June to 1 July. This phenomenon happens because the Earth tilting on its axis according to the seasons sees the poles shift into the dark or the light on either side of the planet. The South Pole experiences this as well, though there are no permanent human settlements south of the Antarctic Circle, unlike the Arctic.

Arctic wildlife

Get to know some of the resourceful creatures who have found a way to live in this bitter terrain




Cetaceans
Narwhals, sperm whales, orca, beluga whales and dolphins all call the icy Arctic Ocean home. Belugas in particular can be found on the polar bear's menu.
Fish
Cod, herring and other white fish prefer cold waters. Arctic fish have a protein in their blood that prevents them from freezing solid.
Seals
Ringed, hooded and harp seals are three of the most common Arctic seals. They're a prime target for hunters like polar bears and killer whales.
Greenland sharks
These are deep-water sharks, similar in size to great whites, that prey on fish, though they enjoy the odd seal too.

Here you can see the siphon really clearly – their darting device

© Getty

Inside a cuttlefish

The hidden secrets of why a cuttlefish is so fascinating

Shape-shifting cuttlefish

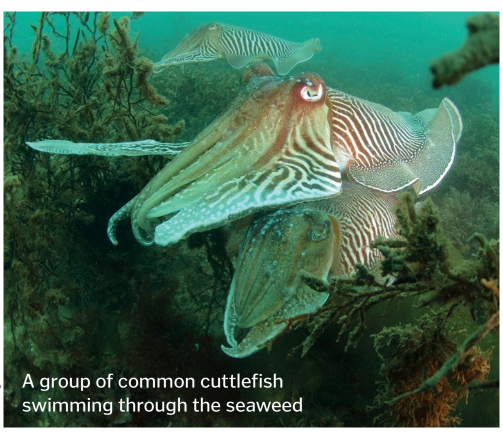
The anatomy of one of the most intelligent animals in the ocean

Cuttlefish belong in a scientific group called 'cephalopods' and are related to octopuses and squid. There are about 120 types worldwide, and of those, three can be found in the UK: the common, elegant and pink cuttlefish. Like their relatives, cuttlefish are one of the most intelligent invertebrates.

They are the superheroes of the underwater world, and have so many amazing adaptations to survive in the wild. Cuttlefish are born with these abilities as soon as they hatch from the pure-black, grape-like eggs they were laid in. These sea grapes, as they are also known, can wash onto the shore after they are dislodged from the marine plants they were attached to following stormy weather. You can also find their internal floats, called cuttlebones, that wash up after they die, soon after mating.

When the young cuttlefish come out of their eggs, they are the size of a fingernail, and they will start to hunt immediately. They themselves are hunted by dolphins, other cuttlefish, fish, sharks and seabirds. But they have clever tricks to escape being eaten.

Cuttlefish generally move quite slowly through the water… until they are spooked. Then they transform into a torpedo, darting backwards and quickly squirting out a cloud of black ink that is stored internally in an ink sac. This confuses their predator, leaving the cuttlefish to skulk away and further impress on their camouflaging skills.



A group of common cuttlefish swimming through the seaweed

© Getty

Masters of disguise

Cuttlefish are masters of disguise. If they are in danger, they can change colour to match seaweeds, sand and rocks with their skin. They do this using cells in their skin called chromatophores. If these cells expand the skin becomes darker, and if they contract the skin becomes lighter. Think about Bruce, the great white shark in *Finding Nemo* – after smelling blood, his eyes expand, and they look really dark. This helps when thinking about what happens to a cuttlefish's skin.

When it's time to mate in spring, males change their colour to the most dazzling zebra stripes, which is mainly to impress females, but also wards off competition. But their amazing abilities don't stop there. They can also change the texture of their skin to match the background and flick sand and gravel over themselves for even more camouflage.

© Sally Sharrock

A cuttlefish showing its impressive black-and-white stripes

NEXT-GE
CONCOR

IS THE FUTURE OF PASSENGER JETS SUPERSONIC ONCE AGAIN?

Words by **Scott Dutfield**

© Boom Supersonic

At the moment the future of international flight is unclear, with travel at its lowest during the ongoing global pandemic. However, planes will inevitably reclaim the skies once the world gets to grips with the coronavirus, and aerospace companies such as Boom Supersonic are ready and waiting with the next generation of supersonic aircraft.

Supersonic flight isn't a novel concept; it's commonly found in militaries around the world. However, commercial flights remain subsonic, except for Concorde's short time in the sky. Boom Supersonic is hoping to change that with its faster-than-sound successor, Overture, a commercial jet that can reach speeds over double the speed of sound at Mach 2.2. This would mean that a trip from Los Angeles to Sydney would take only eight-and-a-half hours as opposed to the typical 15-and-a-half hours.

The next-generation aircraft will be a 65 to 88 seater Concorde-style carrier which can cruise at altitudes of around 18,200 metres – current commercial planes typically cruise at heights of between 10,000 and 12,800 metres.

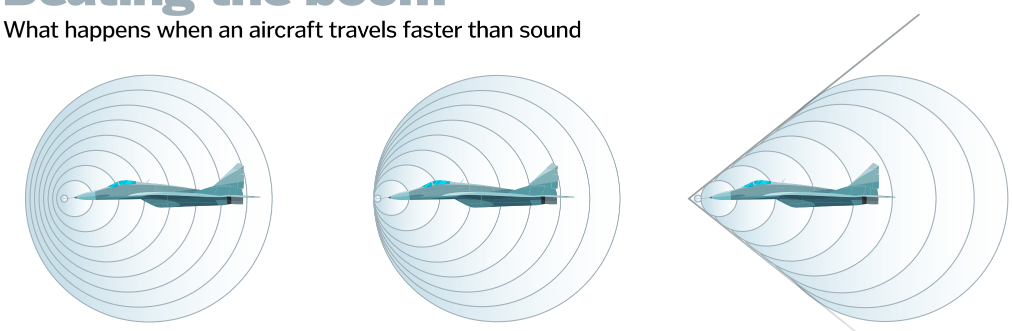
© Boom Supersonic

Boom Supersonic unveiled the highly anticipated demonstrator plane XB-1 in October 2020

To reach the desired supersonic speeds of 1,430 miles per hour, Overture has been designed to reduce the amount of drag – the force acting against a plane as it flies – it experiences. This will be achieved by its sleek aerodynamic body, made from lightweight carbon-fibre material. This material also prevents the expanding and shrinking some other materials experience at supersonic speeds. Large inlets will also be positioned around the aircraft to allow supersonic airflow to seamlessly pass over

Beating the boom

What happens when an aircraft travels faster than sound



BELOW MACH 1
Normal flight
The pressure waves produced by an aircraft travelling through the air slower than the speed of sound are evenly distributed around the aircraft. We perceive these waves as sound.

MACH 1
The speed of sound
When an aircraft reaches the speed of sound, pressure waves gather at the nose. The drag force applied to the plane increases and the airflow is compressed into a non-physical wall, referred to as the sound barrier.

ABOVE MACH 1
Supersonic
When an aircraft reaches supersonic speeds, airflow cannot adjust the compression, causing a shock wave. This wave can be heard as a 'sonic boom' on the ground because the air moves to places of lower pressure.

© Getty

First flight

The first supersonic commercial aeroplane was built by collaborating manufacturers in the UK and France, and was dubbed Concorde. This fast-flying plane made its maiden flight in 1973, carrying passengers at supersonic speeds three years later. Flying under British Airways, Concorde made just shy of 50,000 flights, carrying more than 2.5 million passengers at speeds of 1,350 miles per hour. Concorde's fastest transatlantic flight was in 1996 when it completed the New York to London flight in 2 hours, 52 minutes and 59 seconds. Concorde's supersonic success lasted for 27 years, until a series of events led to its cancellation. In 2000, an Air France Concorde crashed in Paris, killing 109 people on board and four others on the ground. The accident didn't relate to the Concorde's speed, but rather debris on the runway which burst the plane's tyre. Material from the tyre then ruptured a fuel tank. As a result passenger numbers fell, while maintenance costs continued to grow. The tragic events of 9/11 are also thought to have played a role in people's scepticism of flying. By 2003 Concorde was 30 years old and too expensive to maintain, and was scrapped.

20 Concorde planes were built, operated by British Airways and Air France

© Alamy

the plane and slow to subsonic speeds when entering the powerful turbojet engines, which provide massive amounts of thrust.

The passengers flying aboard a supersonic plane don't experience the external speeds, and flying at over 18,000 metres above the Earth's surface, there is almost no turbulence. Passengers may not even notice they have broken the sound barrier when Overture surpasses the speed of sound.

What's also impressive about the Overture's design is that Boom claims it will be made 100 per cent carbon neutral. The aerospace company has teamed up with Rolls-Royce to create a propulsion system that can fly using sustainable aviation fuels (SAF). In early 2019, the engines aboard Boom's proof-of-concept plane, the XB-1, successfully ran on approximately 80 per cent SAF from waste animal fats. Later that year, Boom partnered with Prometheus Fuels to incorporate technology that converts atmospheric carbon dioxide into jet fuel using clean energy. Along with making aircraft design recyclable and exploring noise-reducing technology in its engines, Boom appears to be keeping environmental issues at the forefront of its plane production.

Although Overture remains completed only on the screen of a computer, Boom has manufactured a demonstrator plane to showcase its efforts. Presumably named in honour of the plane that first broke the sound barrier in 1947, the Bell X-1, Boom's XB-1 supersonic is set to secure Overture's future in the skies. The proof-of-concept plane was rolled out in October 2020 and is scheduled to make its first test flight in Mojave, California, this year. The XB-1 is a scaled-down version of the final passenger plane – a third of its eventual size – but will showcase the feasibility of future commercial supersonic flight.

Production of Overture is estimated to begin next year, and it's slated to take flight in 2025, with commercial flights planned by 2029. That is all dependent, of course, on the success of XB-1's California flight tests and the state of a world recovering from global travel restrictions.

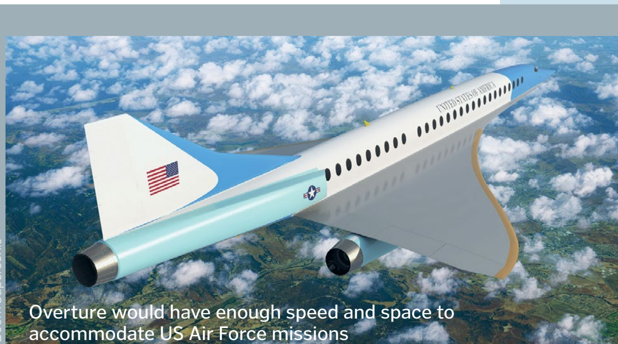
There are more than 500 transoceanic routes ready for Overture

© Boom Supersonic

THE XB-1

Meet the plane that's making commercial supersonic flight possible

AR ZONE! SCAN HERE

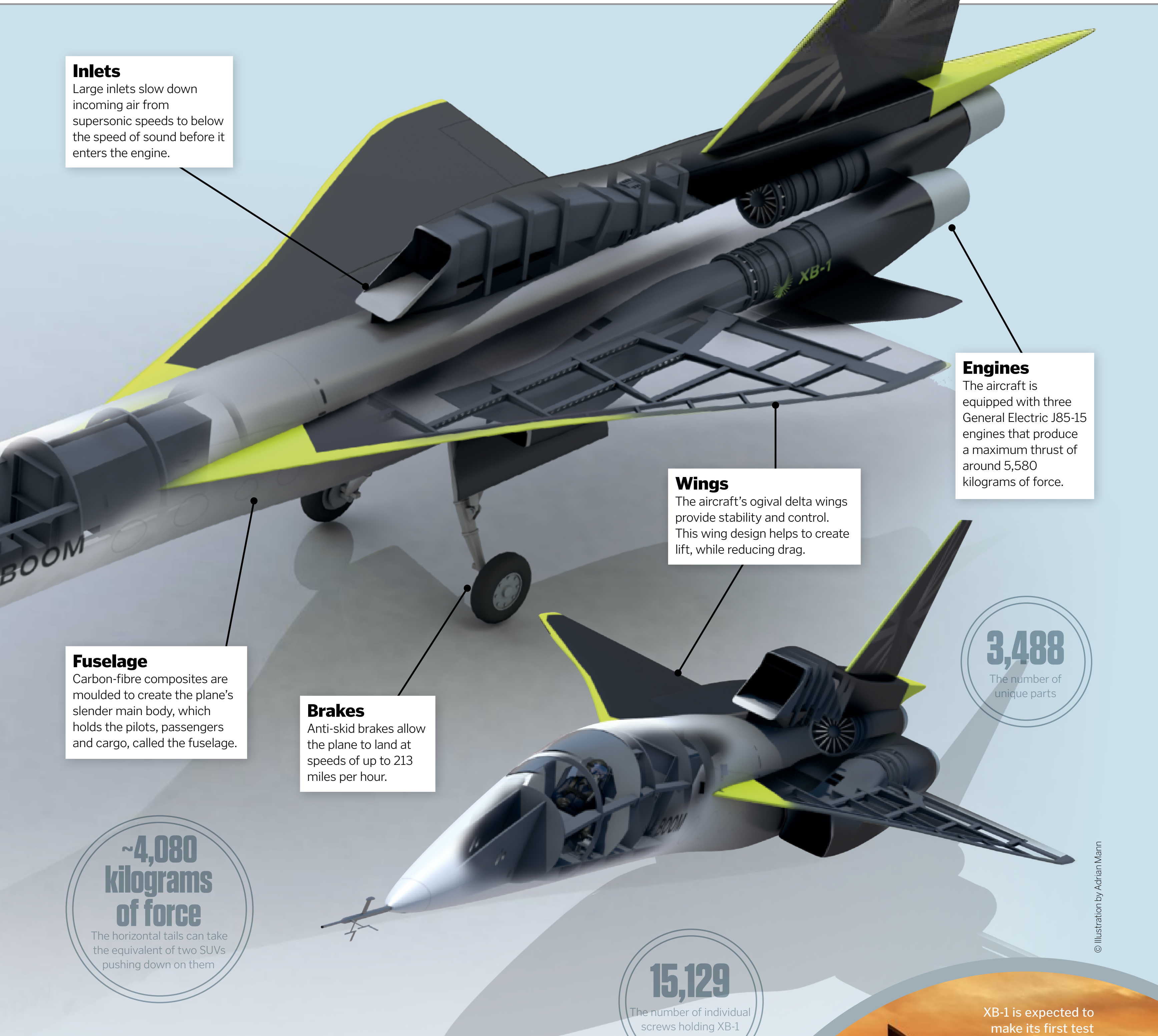


Overture would have enough speed and space to accommodate US Air Force missions

© Boom Supersonic

Faster Air Force

Although Overture could revolutionise commercial flight, it could also transform the transport of military executives. At the end of 2020, Boom was awarded a contract by the United States Air Force (USAF) to explore Overture's applications in the armed services. For now this will take the form of ferrying American leaders around the world in a fraction of the time of current flights. "By cutting travel times, we make it possible for US diplomats and executive leaders to connect more frequently in person, meeting challenges and defusing potential crises with a personal touch. We're so proud to help envision a new way for the Air Force to provide transport for critical government activities," said Blake Scholl, the founder and CEO of Boom. Could this mean that Air Force One might one day get a supersonic makeover?



Inlets
Large inlets slow down incoming air from supersonic speeds to below the speed of sound before it enters the engine.

Engines
The aircraft is equipped with three General Electric J85-15 engines that produce a maximum thrust of around 5,580 kilograms of force.

Wings
The aircraft's ogival delta wings provide stability and control. This wing design helps to create lift, while reducing drag.

Fuselage
Carbon-fibre composites are moulded to create the plane's slender main body, which holds the pilots, passengers and cargo, called the fuselage.

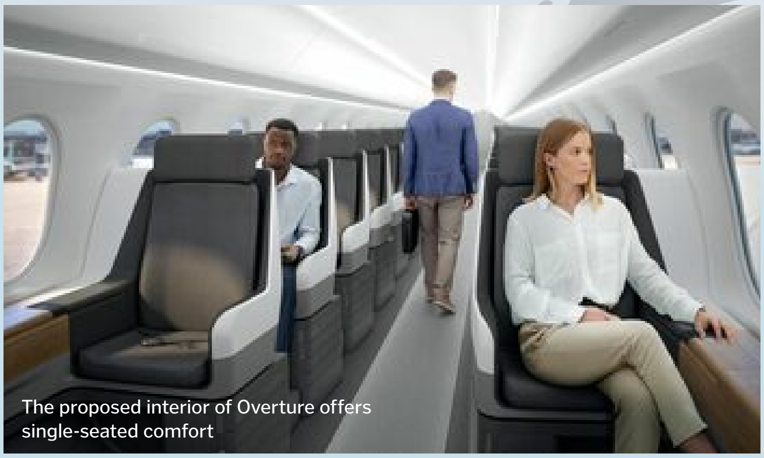
Brakes
Anti-skid brakes allow the plane to land at speeds of up to 213 miles per hour.

3,488
The number of unique parts

~4,080 kilograms of force
The horizontal tails can take the equivalent of two SUVs pushing down on them

15,129
The number of individual screws holding XB-1 together

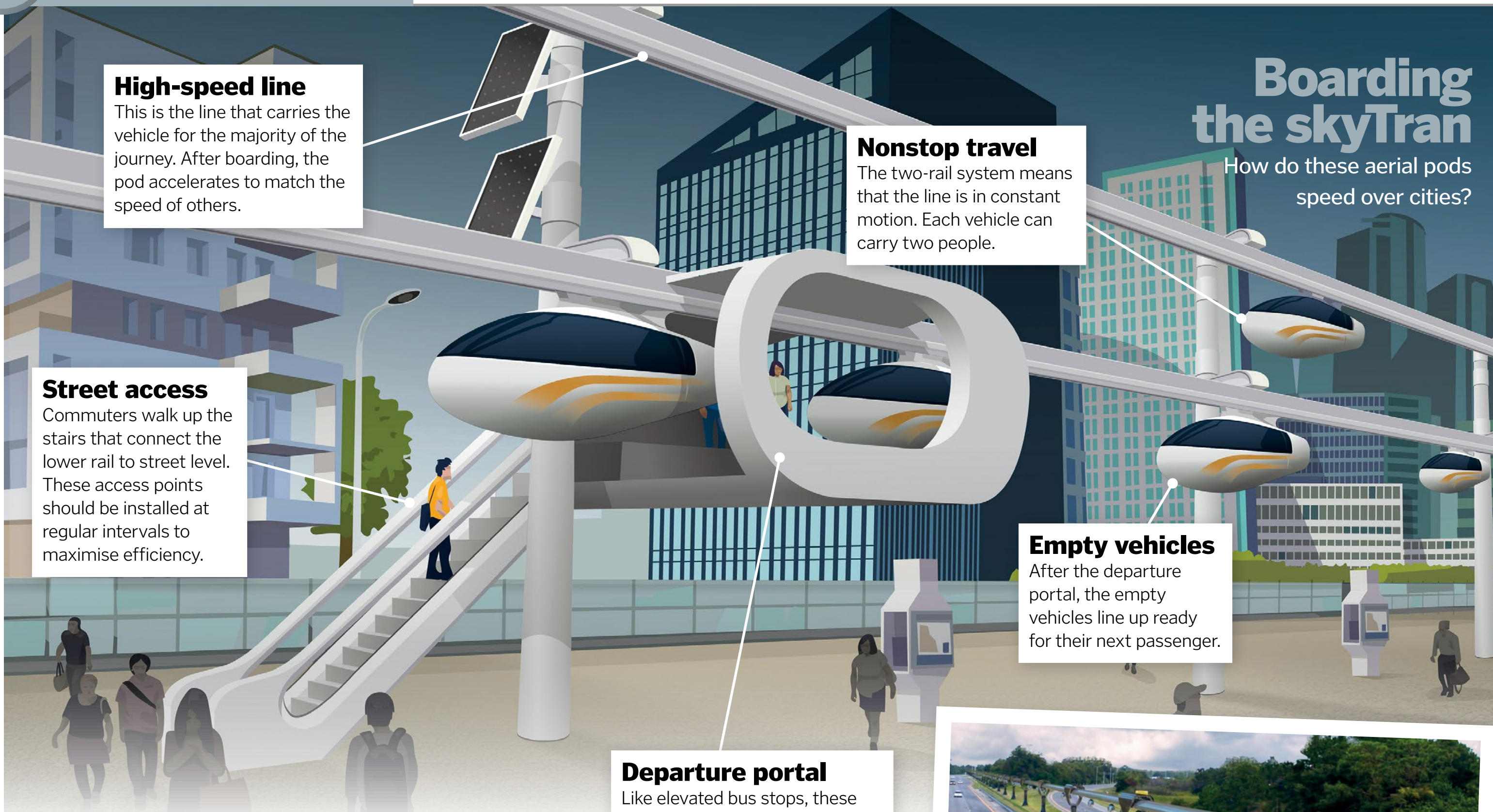
© Illustration by Adrian Mann


The proposed interior of Overture offers single-seated comfort

© Boom Supersonic


XB-1 is expected to make its first test flight this year, but an exact date has not yet been set

© Boom Supersonic



Commuting in the future

SkyTran is an evolving concept aiming to lift public transport off the ground and eliminate city traffic


Elevated rails don't take up much ground space

Cities are densely populated regions teeming with activity, home to a vast variety of job opportunities. But when an area becomes popular with people, packed streets and laborious commutes are never far behind. If you've ever found yourself becoming agitated stuck in a standstill queue of vehicles between you and your destination, the idea of flying above it might sound ideal.

This is the intention behind skyTran. First envisioned in 1990 by American aerospace engineer Douglas Malewicki, the concept has since developed, bringing it closer to reality today. As the problem of traffic escalates in cities around the world, personal rapid-transit systems are becoming more valuable as a solution to reduce travel times in urban areas. Small, electrically powered pods are designed to attach to a network of elevated rails. While moving at high speeds, these vehicles won't need to stop for other passengers to board or depart. Over busy streets, they'll travel at speeds of 50 miles per hour, and between cities this can increase to over 200 miles per hour.

Buses, trains and other forms of public transport can be uncomfortable and stressful places, and can become stuffy and cramped at the busiest travel times. However, skyTran commutes could whisk you through the air in your own personal pod. Installed with artificial intelligence, each pod travels at the same speed, only slowing to a stop when entering the lower line at the destination point.

For the system to work, these towering lines will need to cover large urban areas with a network of pathways. When the passenger selects their desired location, the automated vehicle should effortlessly cross onto new lines without slowing down other travellers.


Maglev technology is already being used in commercial transport, operating trains in China, South Korea and Japan

Floating on air

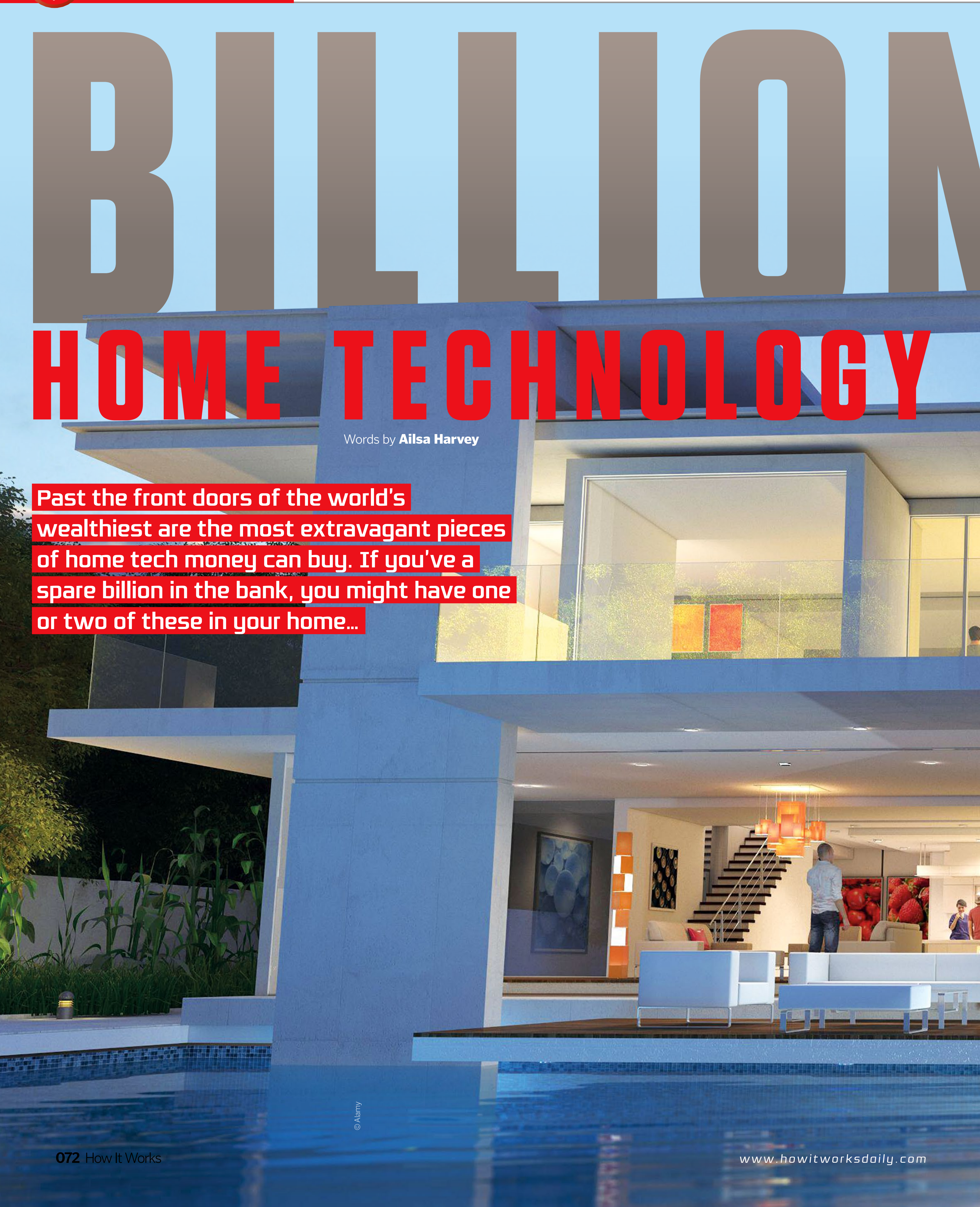
High above the city on a fast-paced upper rail, you might be fooled into thinking you're flying. And with the system running using magnetic-levitation (maglev) technology, this becomes closer to the truth. As a magnetic field is generated, the pods are lifted off the rails, while opposite magnetic poles attract each other to pull the vehicle forward. As this system is repeated using incredibly strong magnets, the entire journey takes place while hovering on a layer of air. By avoiding contact with the bottom of the rail, friction with the rail doesn't slow the vehicles down. Additionally, being an electric system means that while travelling at faster speeds than ground vehicles, journeys should remain smooth and quiet, and will be a more environmentally friendly solution to fossil-fuel-consuming city transport.

BILLION

HOME TECHNOLOGY

Words by **Ailsa Harvey**

Past the front doors of the world's wealthiest are the most extravagant pieces of home tech money can buy. If you've a spare billion in the bank, you might have one or two of these in your home…



© Alamy

AIRES'

Visiting Bill Gates

When you have guests, you often want to go out of your way to keep them comfortable and entertained. You might stock up the fridge and tidy the house as a welcoming gesture. But for billionaires like Microsoft's founder Bill Gates, technology can do all the catering. When visitors arrive at his house, they can enter their temperature and lighting preferences into a device. They are then provided with a pin which tracks them as they navigate the different rooms. The house's sensors track their movement, and the internal climate adapts for them. There are also speakers placed in the walls, so if you want music playing while you're there, the sound can follow you as you walk through the mansion.

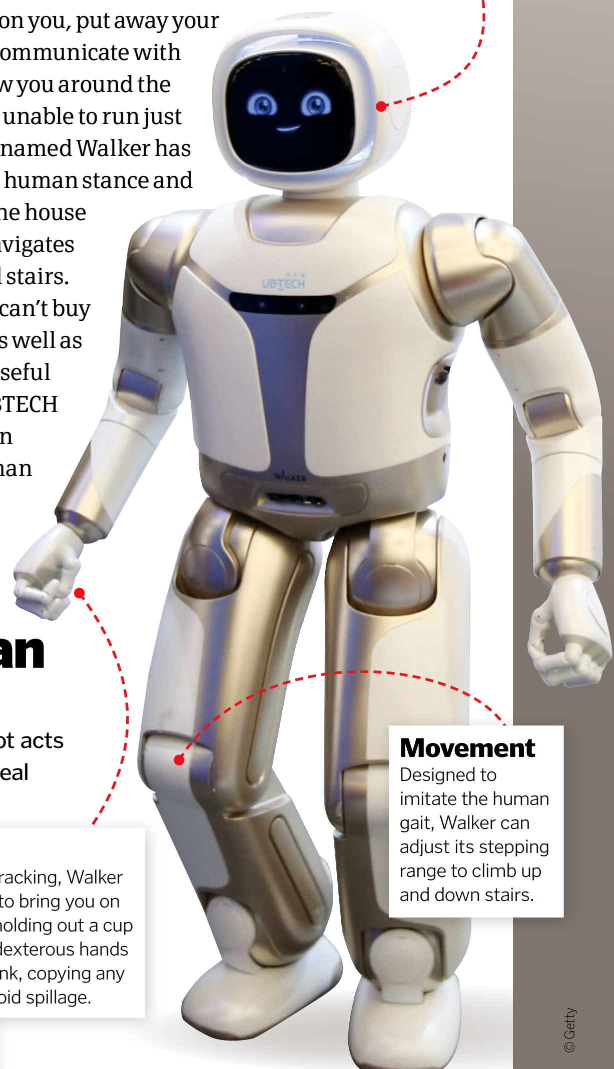
In terms of internal decoration, Gates' home is set to please the eye of any guest, as you can choose your own artwork. $80,000 (£58,000) worth of screens covering the walls allow guests to select any digital art or photograph and project it in an instant.

© Alamy

Bill Gates' home in Medina, Washington, is worth at least $127 million (£92.6 million)

WALKER THE ROBOT BUTLER

Long seen in futuristic films, the latest personal robots are bringing this idea into the real world. Walker is one of the most intelligent creations from UBTECH Robotics. Designed for the home, Walker can answer the door when the doorbell sounds, wait on you, put away your belongings, communicate with you and follow you around the house. While unable to run just yet, the aptly named Walker has mastered the human stance and remembers the house layout as it navigates the floors and stairs. They say you can't buy friends, but as well as performing useful functions, UBTECH has worked on Walker's human skills: it can dance, play and chat.



© Getty

Memory

Acting like another member of the household, Walker remembers your name after you are initially introduced.

Human skills

How this robot acts like the real deal

Go fetch

With advanced tracking, Walker can find objects to bring you on demand. When holding out a cup to the robot, its dexterous hands can refill your drink, copying any movement to avoid spillage.

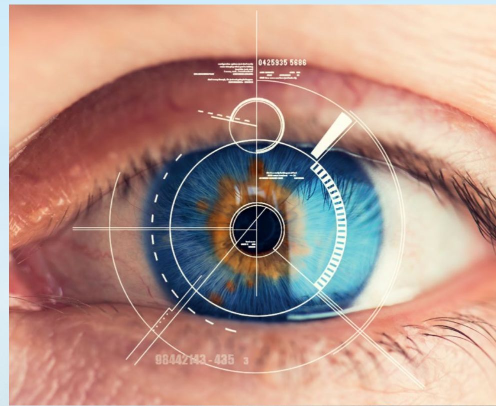
Movement

Designed to imitate the human gait, Walker can adjust its stepping range to climb up and down stairs.

Walker's improved coordination means the robot can pour drinks with no spillages

ULTIMATE SECURITY

How can the world's richest keep their luxury mansions safe?



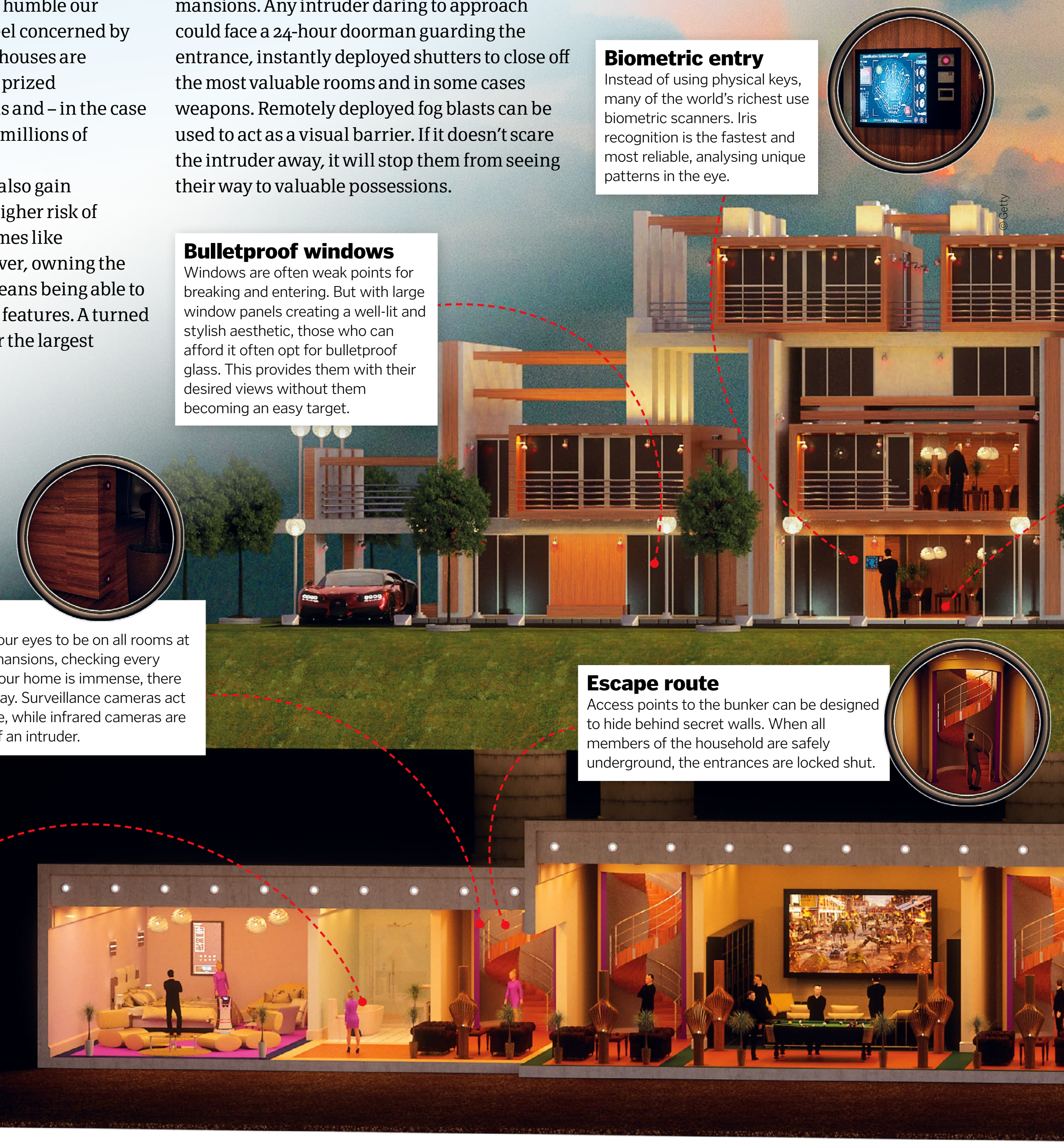
Biometric iris scanners are estimated to be around ten-times more accurate than using fingerprints

It doesn't matter how lavish or humble our homes are, most people will feel concerned by the prospect of a robbery. Our houses are personal to us, containing our prized possessions, sentimental items and – in the case of some of the richest people – millions of pounds worth of technology.

As people gain money, they also gain attention. They are often at a higher risk of burglary, as well as darker crimes like kidnapping for ransom. However, owning the most desirable homes often means being able to afford some of the top security features. A turned key in the door isn't enough for the largest mansions. Any intruder daring to approach could face a 24-hour doorman guarding the entrance, instantly deployed shutters to close off the most valuable rooms and in some cases weapons. Remotely deployed fog blasts can be used to act as a visual barrier. If it doesn't scare the intruder away, it will stop them from seeing their way to valuable possessions.

Escaping threats

What systems are available to detect intruders and protect billionaires from danger?



Biometric entry

Instead of using physical keys, many of the world's richest use biometric scanners. Iris recognition is the fastest and most reliable, analysing unique patterns in the eye.

Bulletproof windows

Windows are often weak points for breaking and entering. But with large window panels creating a well-lit and stylish aesthetic, those who can afford it often opt for bulletproof glass. This provides them with their desired views without them becoming an easy target.

Infrared cameras

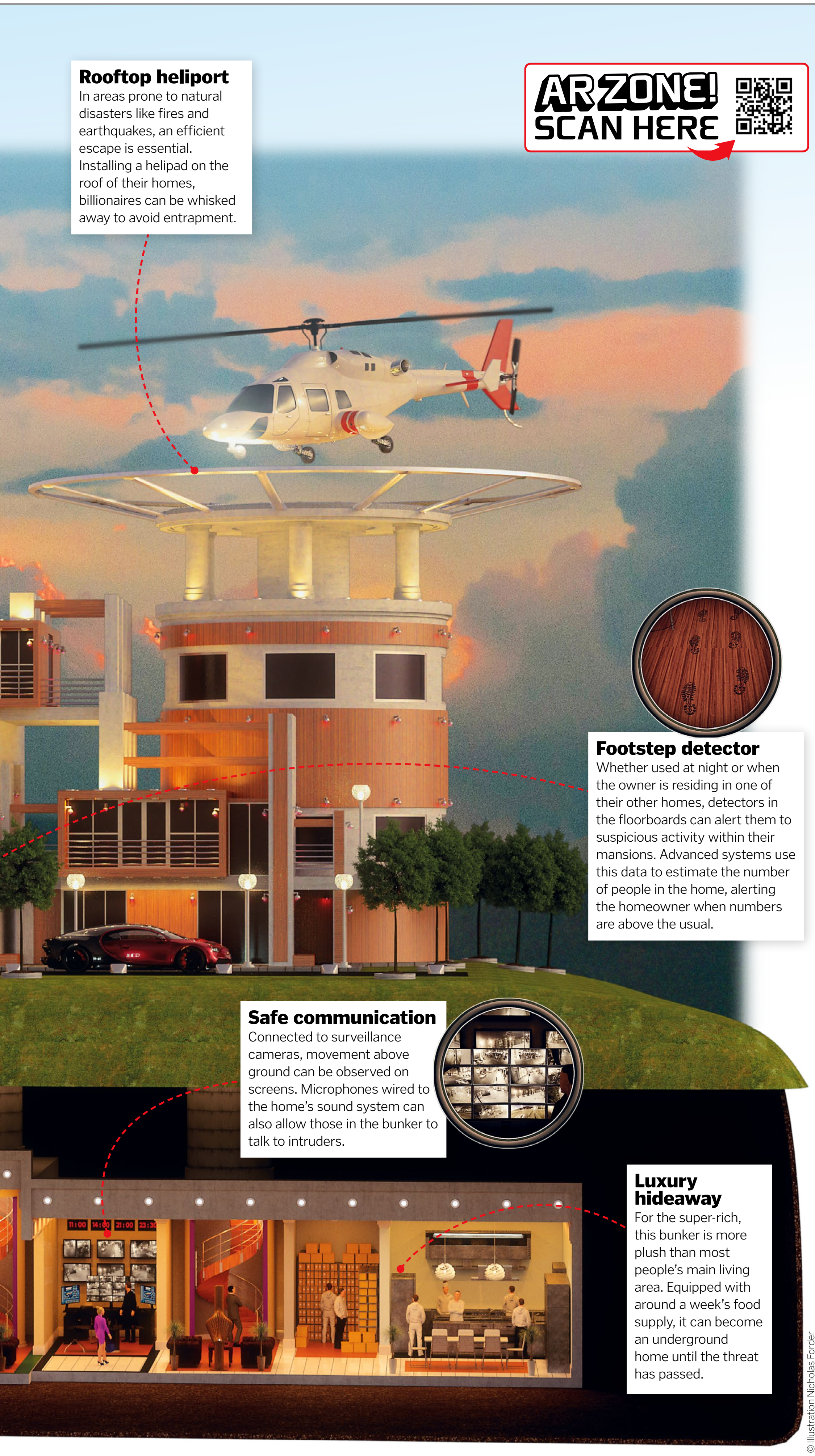
In most houses, it's impossible for your eyes to be on all rooms at once. But for those owning sizable mansions, checking every room simply takes too long. When your home is immense, there are areas you might not visit every day. Surveillance cameras act as essential extra eyes on your home, while infrared cameras are effective in locating the body heat of an intruder.

Escape route

Access points to the bunker can be designed to hide behind secret walls. When all members of the household are safely underground, the entrances are locked shut.

Biological wash

This may look like your average shower, but for a price of a few thousand pounds you can attach a biological washing system. In the event of a biological attack, toxic chemicals and biological agents can be washed away instantly from home.



Rooftop heliport
In areas prone to natural disasters like fires and earthquakes, an efficient escape is essential. Installing a helipad on the roof of their homes, billionaires can be whisked away to avoid entrapment.

AR ZONE! SCAN HERE

Footstep detector
Whether used at night or when the owner is residing in one of their other homes, detectors in the floorboards can alert them to suspicious activity within their mansions. Advanced systems use this data to estimate the number of people in the home, alerting the homeowner when numbers are above the usual.

Safe communication
Connected to surveillance cameras, movement above ground can be observed on screens. Microphones wired to the home's sound system can also allow those in the bunker to talk to intruders.

Luxury hideaway
For the super-rich, this bunker is more plush than most people's main living area. Equipped with around a week's food supply, it can become an underground home until the threat has passed.

© Illustration Nicholas Forder

Playground for the rich

Amazon founder Jeff Bezos' entertainment facilities demonstrate how the richest relax

Golf simulation

For any golf fan wanting to improve on their game, an in-house simulator provides all-weather practise on virtual courses without needing to make a trip to the local golf course. For Jeff Bezos, this purchase was to accompany the real golf course that he already owns, which his mansion overlooks.

Simulators analyse your swing, while the screen records details of each shot

© Getty

Personal cinemas

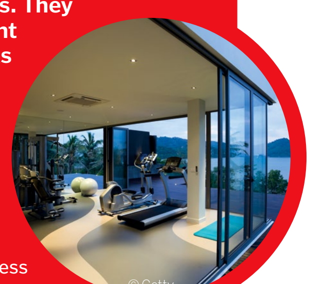
Who doesn't like to put their feet up and watch a new series, start a movie marathon or see what's on TV? People can spend many hours fixated on the box in the corner of the living room. But when money has no limits, what size TV do you get? A popular feature for many is a movie room. With their own personal cinemas, members of the family and any guests can often have a row to themselves as the screen fills an entire wall.

Bezos' house has a entertainment room with a home cinema

© Alamy

Indoor exercise

Gyms have become increasingly popular as people strive for healthier bodies and wish to look after their mental wellbeing. However, you won't find some of the richest individuals in these overcrowded facilities. They have all the equipment they need at home. As part of his personal gym, Jeff Bezos' Manhattan home comes with a yoga studio.



Smart-home gyms allow users to track their progress across equipment

© Getty

KEEPING SUPERCARS

With the high prices of these cars, it's worth spending more to keep them secure

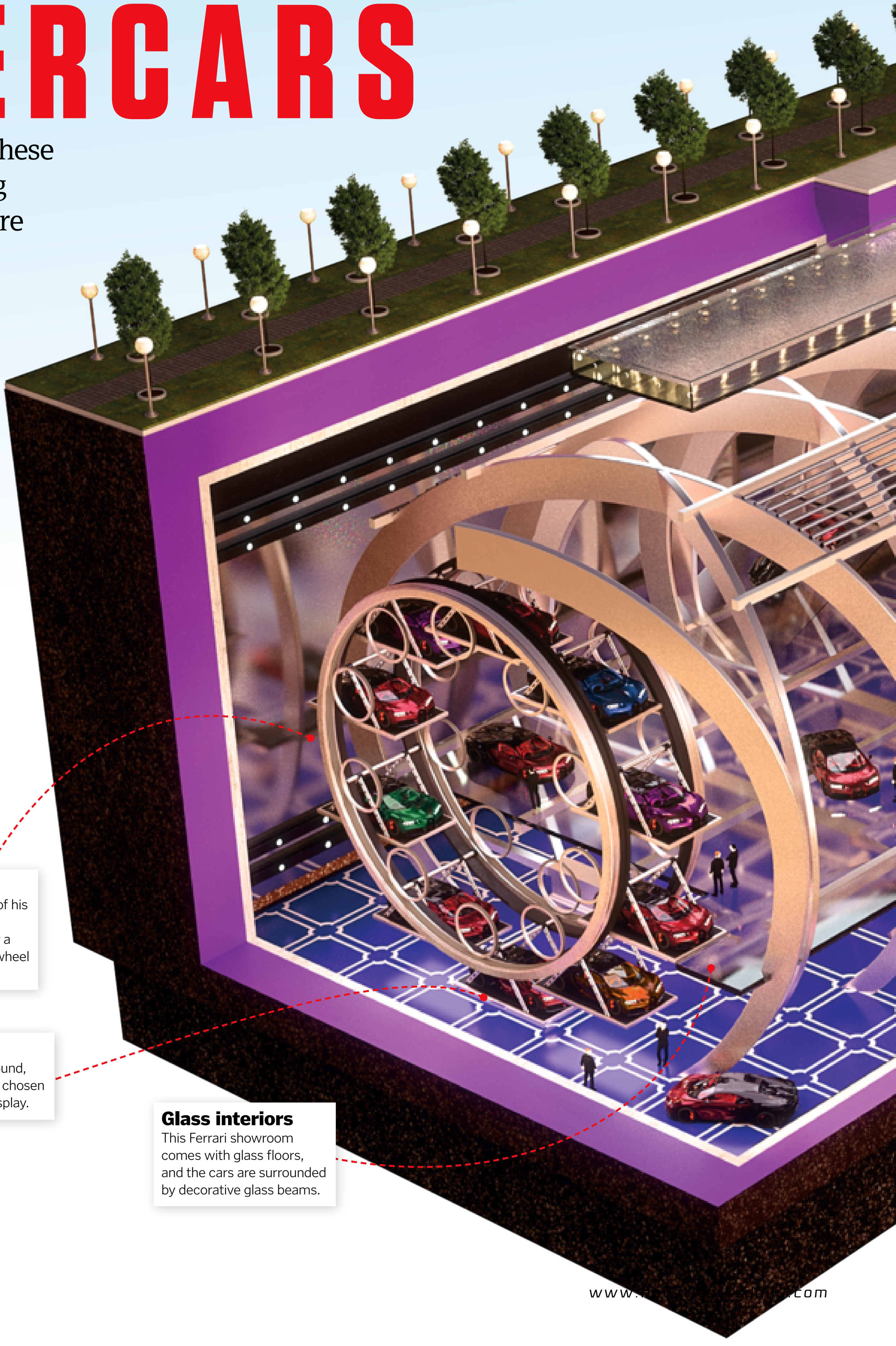
When you can afford the top cars on the market, the next question is where to store them. While some are content with one car, most of the super-rich enjoy a selection, putting them on display in extravagant home garages.

For Oprah Winfrey, who lives high in the mountains of Telluride, Colorado, the most regular threat to her drive is snow. For this reason she invested in a heated driveway to ensure her wheels are ready for a spin despite a night's snowstorm.

Some super-rich car lovers invest many millions into car storage, often giving their vehicles their own room in the house. As opposed to leaving their cars parked outside, car elevators have been invented to carry the car and its driver into the house's designated garage. This means speedy commutes for the driver, getting them onto the road without needing to step outside.

Car carousel

This underground garage was designed by British entrepreneur Jon Hunt to store his many Ferraris



Spinning wheel
Hunt has over 30 cars, but a few of his most prized hold positions on this carousel. When taking one out for a drive, the car is selected and the wheel spins to release it at the bottom.

Parking
Exiting the lift underground, the car is driven into its chosen position to rejoin the display.

Glass interiors
This Ferrari showroom comes with glass floors, and the cars are surrounded by decorative glass beams.

AR ZONE! SCAN HERE

Easy access
When returning home in the car of the day, the billionaire simply drives into a lift on the driveway, which carries the car below ground.

Underground extension
The design adds an extra five-storey chamber underneath the home.

Sizable museum
The entire basement is 24 metres in height, creating a spacious car museum.

Parking space
At 55 metres in length, the garage is about half as long as a football pitch.

5 FACTS ABOUT EXPENSIVE LUXURIES FOR EACH ROOM

1 Bedroom
Dutch architect Janjaap Ruijssenaars has designed a £1.2 million ($1.65 million) floating bed. The design uses strong magnets to keep the user hovering above the ground all night.

2 Bathroom
A bathtub was sold for £1.5 million ($2 million) because it was made of 180-million-year-old petrified wood. Designer Nigel Fenwick discovered the wood while exploring an Indonesian rainforest.

3 Living room
The 370-inch Titan Zeus is the largest TV screen you can buy. Costing £1.17 million ($1.6 million), the screen is made for both indoor and outdoor use.

4 Kitchen
Instead of simply storing and cooling food, smart fridges can analyse the food inside, alerting you to which foods you're running out of and which are going off.

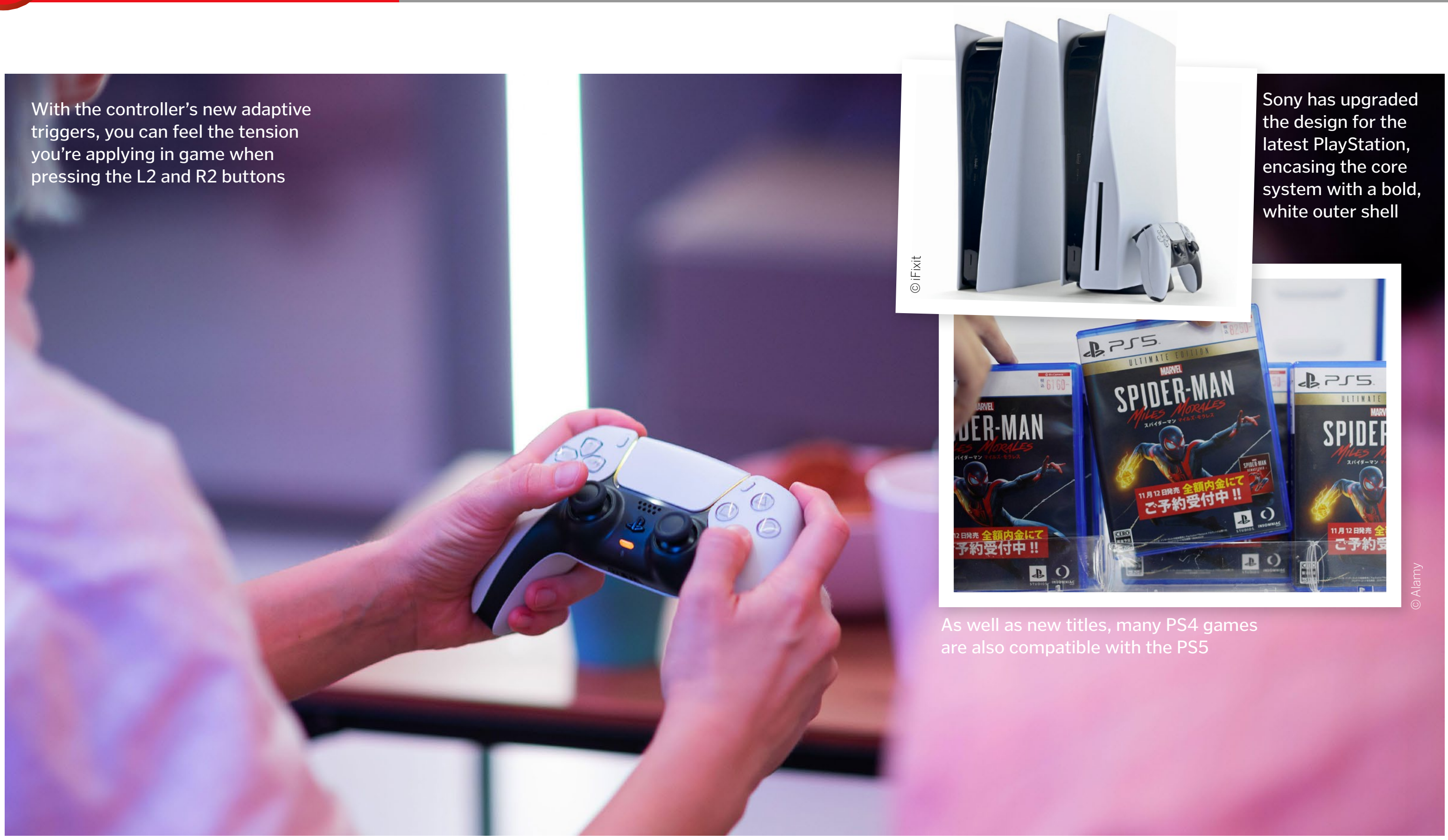
5 Garden
Finding the time to tend to the plants in your garden can be difficult, so why not have a computer monitor each plant? That's what Bill Gates did to his favourite maple tree. When it gets dry, water is pumped to the roots.

Jarvis: meet Mark Zuckerberg's assistant

When the creator of Facebook sought the help of artificial intelligence to assist him in his home, he was looking for something personal. Instead of installing commercially available software, Zuckerberg designed his own. Inspired by *Iron Man*, 'Jarvis' connects to his household appliances, including his cameras, speakers, lights and toaster. Now Zuckerberg doesn't even need to make his own toast, as text and voice-operated Jarvis can do that for him. With voice recognition, Jarvis can detect who is asking, and even plays different music based on the known preferences of the person who asked.

Instead of running around his home to find his family members, Zuckerberg can just ask Jarvis where his wife and kids are. Using a similar system to Facebook's own face recognition, the assistant can locate known faces around the house or tell him who is at his front door by connecting to the door's camera.

Zuckerberg prefers to control Jarvis with his phone than with voice commands



With the controller's new adaptive triggers, you can feel the tension you're applying in game when pressing the L2 and R2 buttons

© Alamy

© iFixit

Sony has upgraded the design for the latest PlayStation, encasing the core system with a bold, white outer shell

As well as new titles, many PS4 games are also compatible with the PS5

© Alamy

PlayStation 5 teardown

Peek inside Sony's latest console to see how the PlayStation has levelled up

If you're a keen PlayStation gamer, you will have been eagerly awaiting the release of the PlayStation 5 in November 2020. With its sleek new look and high-quality graphics, it quickly became a worthy contender for its Xbox rival, whose equivalent console was launched in the same month. The PlayStation 5 has had a makeover to keep it distinct from other consoles, with its glossy white exterior and blue lights providing a futuristic aesthetic.

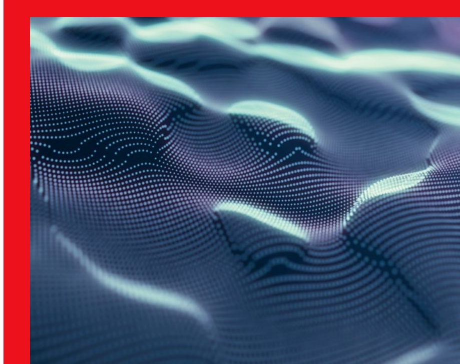
Although some gamers held strong opinions about its appearance, most cared only about its performance. Compared to its predecessors, the PlayStation 5 has many advanced features, demonstrating recent evolutions in gaming technology. It provides players with much faster loading times, controllers with built-in microphones and upgraded haptics and even serves as a 4K Blu-ray player, extending its capabilities beyond gaming.

Sony has also thought about the small, yet important features. Along with upgrades to cooling technology, helping to improve the console's performance, the PlayStation 5 has a dust filter. As with Sony's previous consoles, large cooling fans draw in the surrounding air to cool down the processors, which can result in an accumulation of dust that can cause the console to overheat. The latest PlayStation comes with a filter and compartment to easily remove the build-up of dust and grime. This is just one of many small adaptations that users will appreciate with their new console.

"The PlayStation 5 has many advanced features"

Audio immersion

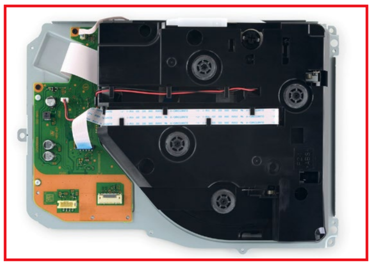
Gaming is a form of escapism. With the ability to transport the player into endless new worlds, Sony's next-generation PlayStation needed to step up this experience. Alongside the PlayStation 5, Sony released Tempest 3D AudioTech. At first this is only being installed into Sony's PULSE 3D wireless headphones, but eventually you should be able to experience this effect through your own speakers as you play. The incredibly immersive audio enables your brain to locate the exact direction and distance of the slightest noise – even singling out individual raindrops. Equipped to designate sounds at hundreds of precise locations, this gives you a more realistic feeling of being transported away from your living room and to the centre of the game.



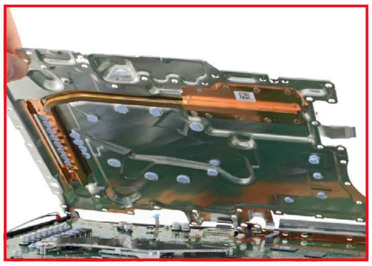
© Getty

The PlayStation's headphones use object-based spatial sound technology

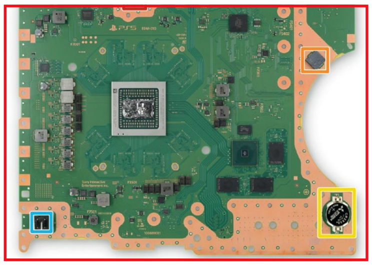
1 Omnidirectional fan
Sliding off the white panels reveals the system's cooling fan. This pulls in air from both sides of the console for faster and more efficient cooling.



2 Optical drive
To read game and video discs, this optical drive is connected to its own motherboard. If you replace it with another drive, it won't read the inserted discs.



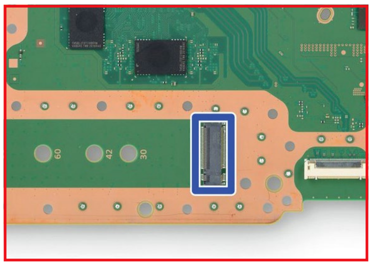
3 Cooling pipe
As heat is generated from the console's custom graphics and central processors, this pipe channels heat away from the components and towards the fan.



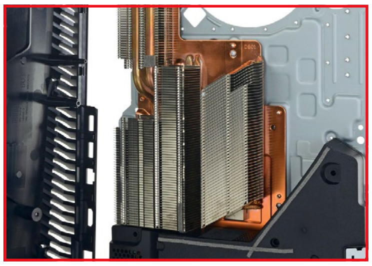
4 CPU
The eight-core AMD Zen 2 central processing unit used in the PS5 has a clock speed of 3.5 GHz for speedier loading times and less lag.

Console teardown

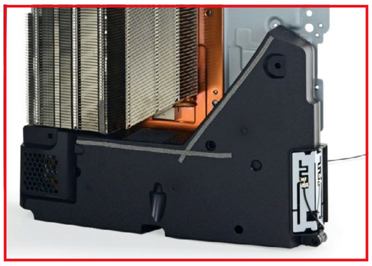
Take a closer look at the technology bringing high-quality gaming to your screens



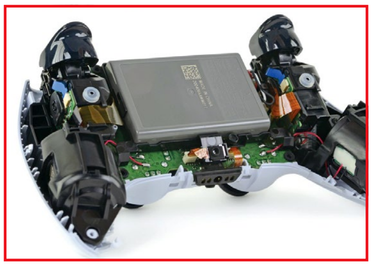
5 Storage expansion
The PlayStation 5's internal storage is integrated into the motherboard, but this M.2 SSD slot will enable users to add expansions if they run out of space.



6 Heat sink
As the heat rises upwards through the cooling pipe, it is dispersed across a wider area by the heat sink's silver fins before leaving the console.



7 Power supply
Within this black case, the power pack provides 350 watts. This is 100 watts more than the original PlayStation 4's maximum wattage.



8 DualSense haptics
With much bigger haptic motors than previous controllers, feedback from the controller provides a more immersive experience when gaming.

How bricks are made

A look at how the world's building blocks are created

If the well-known story of *The Three Little Pigs* teaches us anything, it's that bricks are tough – very tough. But not only are they hard, they're pretty cheap and easy to produce, too, which is why for the last 5,000 years they've been one of the cornerstones of construction around the world.

Making a brick is like making a very hard cake. First brick-makers take the ingredients – modern bricks are usually made of clay, but they can be made of other substances such as shale or concrete. They can also include smaller amounts of other materials designed to change the brick's colour or texture. Then everything is ground down to a smooth consistency and mixed with water to make it nice and malleable. The bricks are then set into the desired shape using one of three processes, called extrusion, moulding or pressing, with extrusion being the most popular one.

Once the bricks are formed they're dried out for around 24 hours at temperatures of 100 degrees Celsius; this is to get rid of any extra moisture so the bricks don't crack. The bricks then go into a kiln – a really hot oven – and are baked up to temperatures of around 1,000 degrees Celsius, then left to cool, a process that makes them really hard. When it's all finished the bricks are stacked, wrapped up and padded, ready for storage or transport.

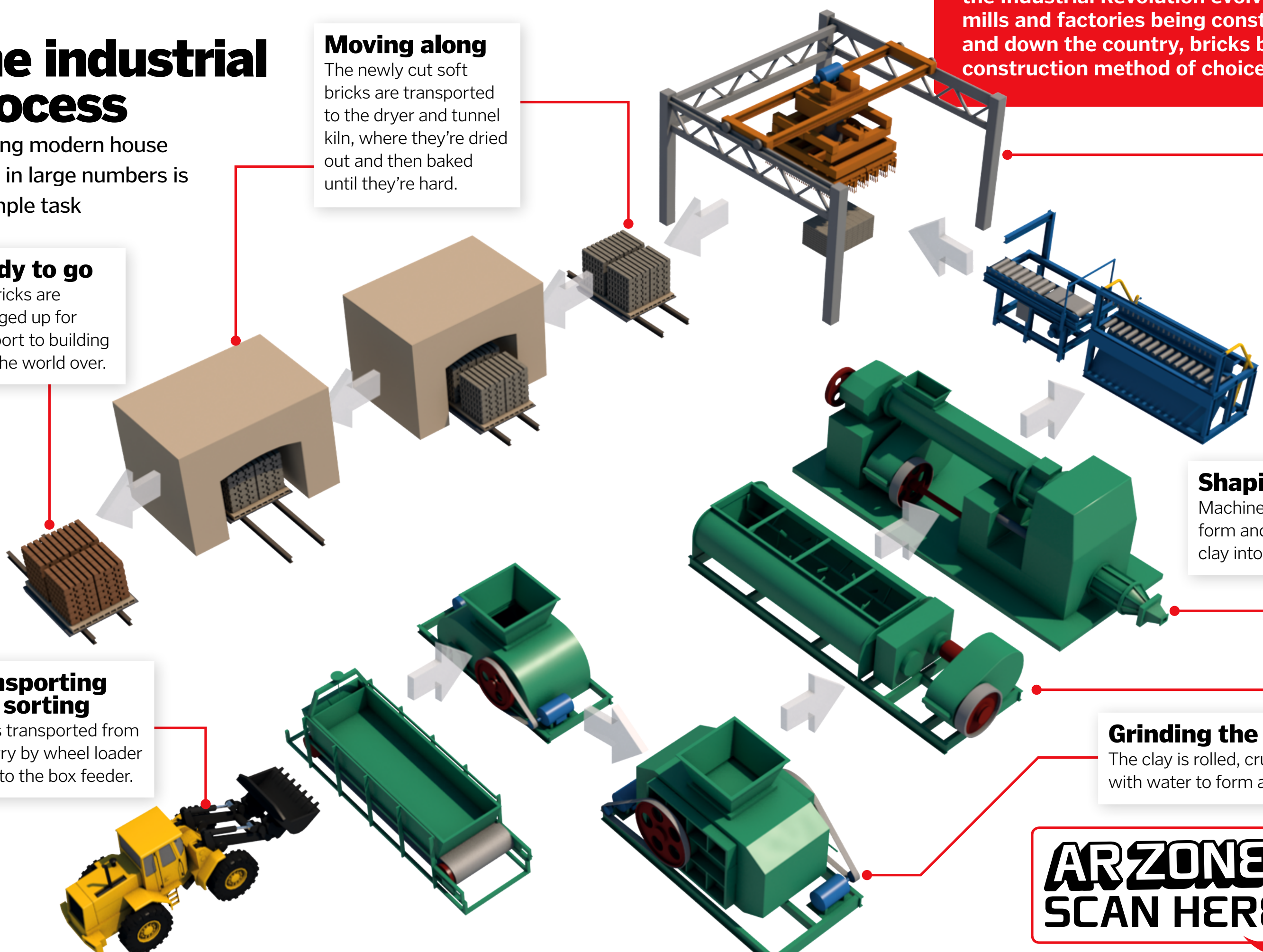
The Romans introduced the humble brick to Britain in structures like Hadrian's Wall

Foundations of history

From Roman aqueducts to Medieval castles, humans have been building with bricks for millennia. They are thought to have first been used in ancient Mesopotamia and were originally baked in the Sun rather than in a kiln. The Romans brought the modern brick to Britain, but they fell into disuse after the Roman legions withdrew. After the Great Fire of London, the king ordered that buildings should be constructed to be more resistant to fire, and bricks again found themselves in widespread use. As the Industrial Revolution evolved with mills and factories being constructed up and down the country, bricks became the construction method of choice.

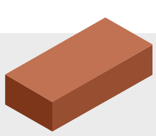
The industrial process

Creating modern house bricks in large numbers is no simple task

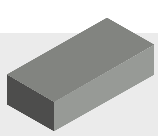


AR ZONE! SCAN HERE

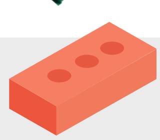
Different types of bricks



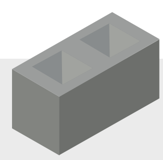
Common burnt clay
Properties: Strong and cheap to manufacture
Commonly used: General construction, walls, houses



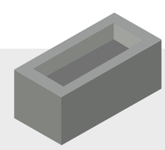
Sand lime
Properties: Smoother appearance than clay
Commonly used: Ornamental works in buildings, masonary works



Engineering
Properties: Strong and water resistant
Commonly used: Ground works, sewers and retaining walls

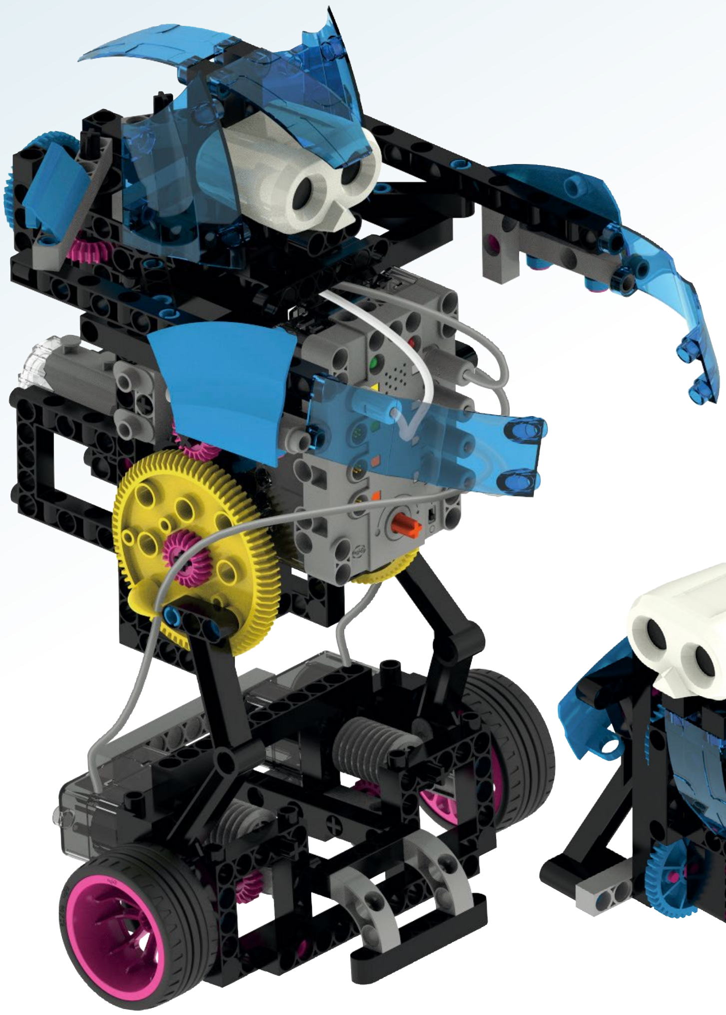


Concrete
Properties: Heat resistant and inexpensive
Commonly used: Fences and façades



Fly ash clay
Properties: Less porous and more affordable than clay
Commonly used: Houses and high-rise structures

WIN! A ROBOT KIT



This month we are giving you the chance to win the Robotics Workshop experiment kit by Thames & Kosmos. From a robotic arm to a butler robot, you can build and program the many robotic possibilities of this creative STEM kit

thamesandkosmos.co.uk

For your chance to win, answer the following question:

What is the chemical symbol for uranium?

a) **Xe** b) **U** c) **Pb**

Enter online at **howitworksdaily.com** and one lucky winner will win!

Terms and Conditions: Competition closes at 00:00 GMT on 11 March 2021. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: **www.futuretcs.com**. Entries must be received by 00:00 GMT on 11/03/2021. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

Supersonic space parachutes

How space pushes our ordinary parachute technology to the extremes

On the face of it, space parachutes might look like ordinary parachutes – cloth canopies attached to their cargo by a series of ropes – but these parachutes are anything but. After hot, fast atmospheric entry, they open into thin atmospheres, rushing past at supersonic speeds. Their job is to slow a payload down to the speed of a push bike, and if they fail, the consequences can be catastrophic. The precious payloads they protect might be multi-billion-dollar rovers bound for the surface of Mars, or four-strong human crews returning to planet Earth.

Space parachutes burst into the sky from explosive mortars, whipping into turbulent airstreams moving faster than the speed of sound. As they move from their packed shape to their deployed shape, they can pass through infinite possible conformations depending on micro-fluctuations in the air around them. One unexpected change in pressure can fold the canopy, snap a cord or even tear a piece of fabric clean away.

The unpredictable conditions that these parachutes face, and the catastrophic consequences of a failure, mean that every detail matters, from the shape of the canopy to the thickness and positioning of the stitching that holds it all together. The two most successful designs are the 'disc gap band' – a circle of fabric and a band of fabric – and the 'ring slot' – concentric rings of fabric. Both have air gaps, which help to reduce the shock when the parachute opens and keep the canopy stable in turbulent air.

Engineers have been testing NASA's Orion parachutes by dropping the capsule from an aeroplane

© NASA

"One unexpected change in pressure can fold the canopy"

The ESA tests a 35-metre space parachute in preparation for the upcoming ExoMars mission

© ESA

Supersonic parachutes and the search for life

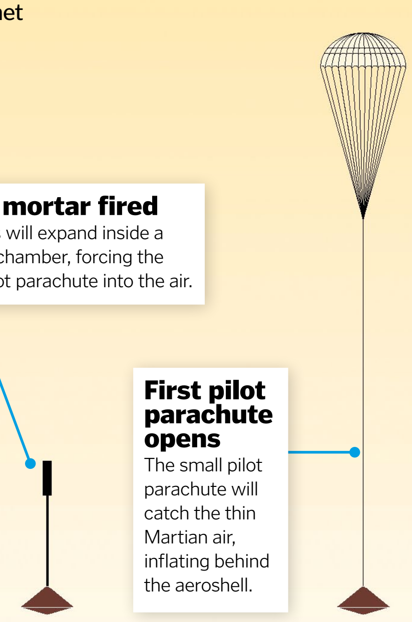
In 2023, the European Space Agency (ESA) will fly the largest ever space parachute over the surface of Mars. The 35-metre canopy will soften the landing of the Rosalind Franklin rover and surface platform, which are visiting the Red Planet in search of life. They will enter the atmosphere at a speed of 13,000 miles per hour before slowing in the thin Martian air to around 1,050 miles per hour. Two parachutes will then deploy in sequence: a compact 'disc-gap-band' chute followed by the record-breaking 35-metre 'ring slot' chute.

This artist's concept shows what the ExoMars rover might look like on Mars

© ESA

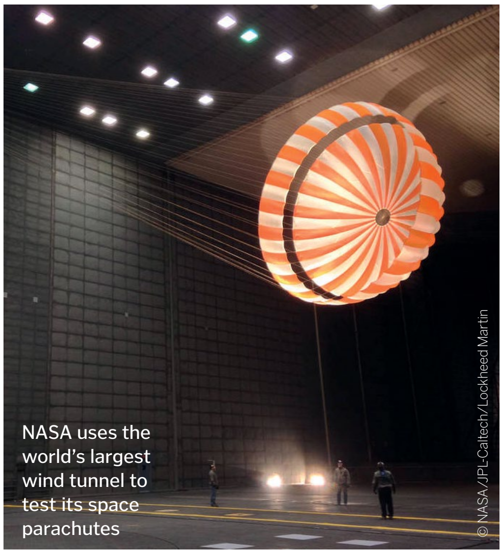
Parachuting over Mars

ExoMars will carry the largest parachute ever to fly over the Red Planet



First mortar fired
Hot gas will expand inside a sealed chamber, forcing the first pilot parachute into the air.

First pilot parachute opens
The small pilot parachute will catch the thin Martian air, inflating behind the aeroshell.



NASA uses the world's largest wind tunnel to test its space parachutes

How do you test them?

The exact conditions that space parachutes will encounter are almost impossible to recreate. The air they interact with moves in chaotic and unpredictable patterns, wind speeds change as they descend and the pressure is constantly shifting. To find out how a parachute might behave in the field, engineers perform an arsenal of digital and physical tests.

The first stages of these tests happen on the ground. Engineers probe parachute materials to examine how their shape changes under stress. They build scale models and fly them in supersonic wind tunnels, and they build full-size models then fly them in enormous hangars.

The final stage is real deployment in the skies over Earth, often attached to a mock-up of the payload the parachutes will one day help to land. These test chutes fly into the sky on helicopters, planes or rockets before dropping towards the ground at supersonic speeds.

Tests allowed NASA engineers to find out what would happen if Orion's parachutes failed to deploy

4 Parachutes needed to land the ESA ExoMars payload on Mars

20,000 mph The speed of spacecraft re-entering Earth's atmosphere

1% Mars' atmosphere is just a fraction of the density of Earth's

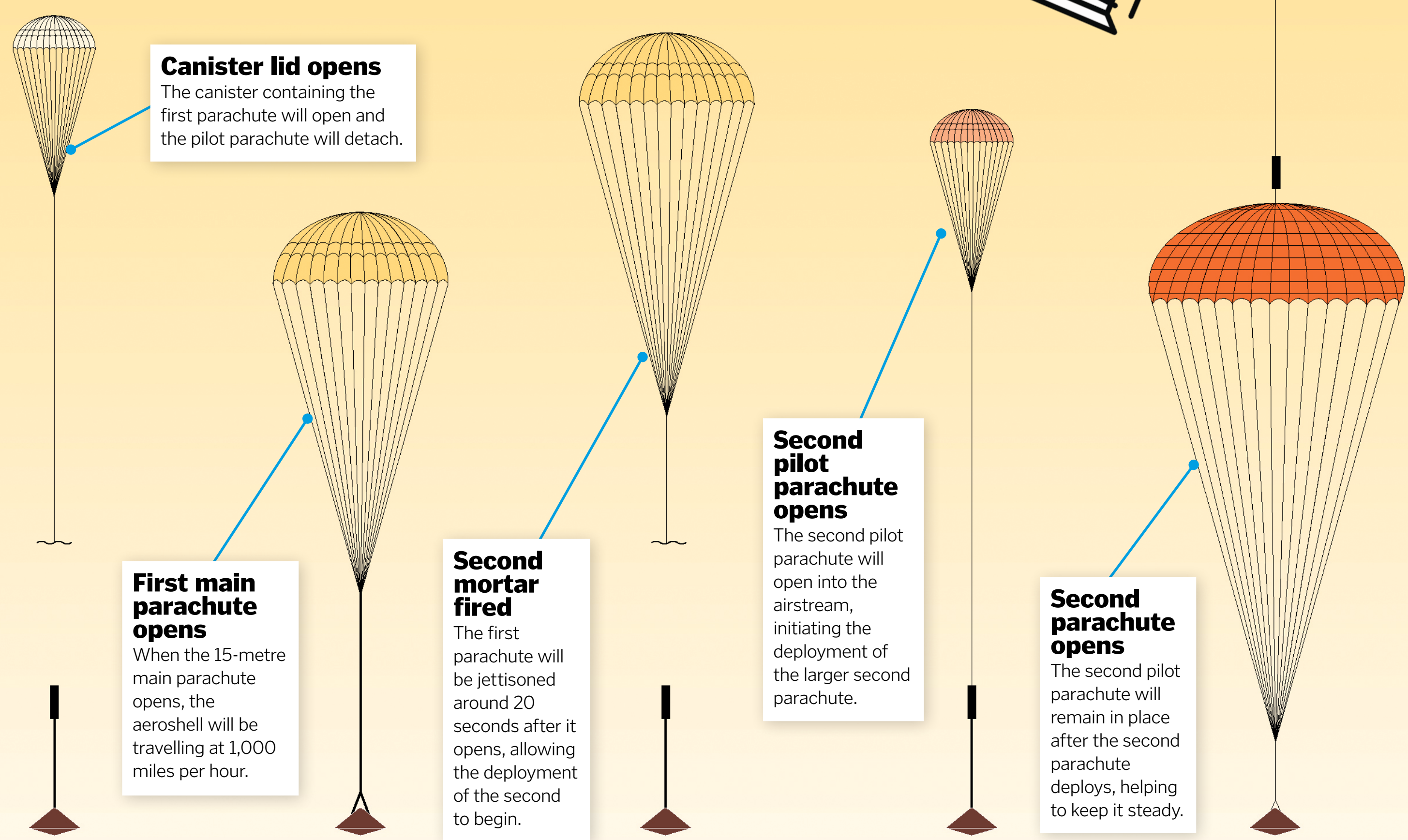
11 Parachutes needed to land the NASA Orion crew module on Earth

Parachute fabric is a plain, dense weave called broadcloth

20

20mph Safe landing speed for humans returning to Earth

Space parachutes are made from polyester and nylon

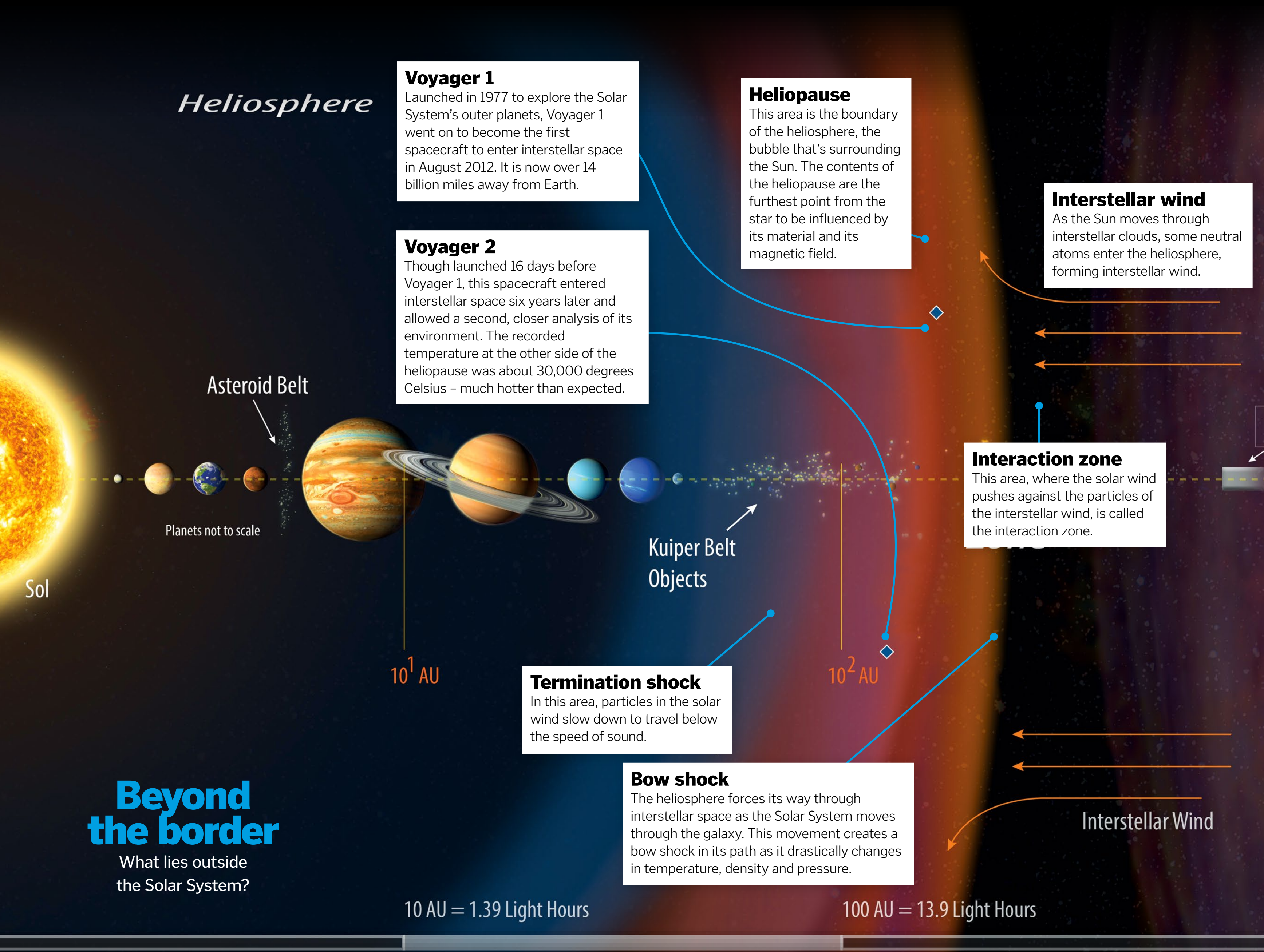


What's in interstellar space?

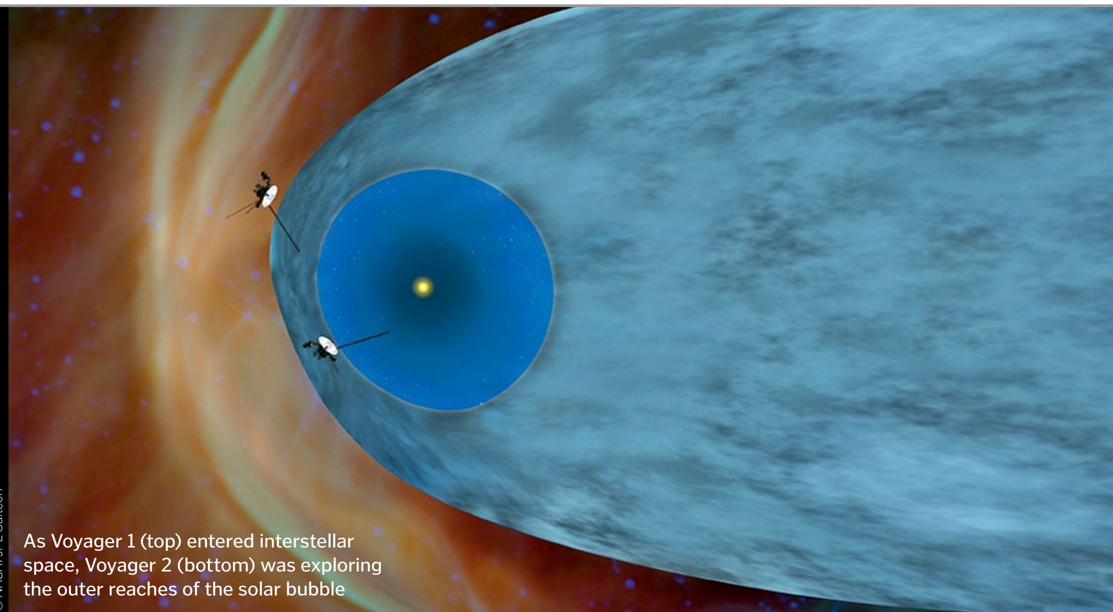
The darkest regions of the galaxy birth the brightest stars

Despite being as close to a vacuum as can be achieved within our galaxy, interstellar space is far from empty. Beyond the Sun's surrounding bubble, which is created by the solar wind, interstellar space is defined as the region of space that is no longer impacted by the outflow of material from surrounding stars.

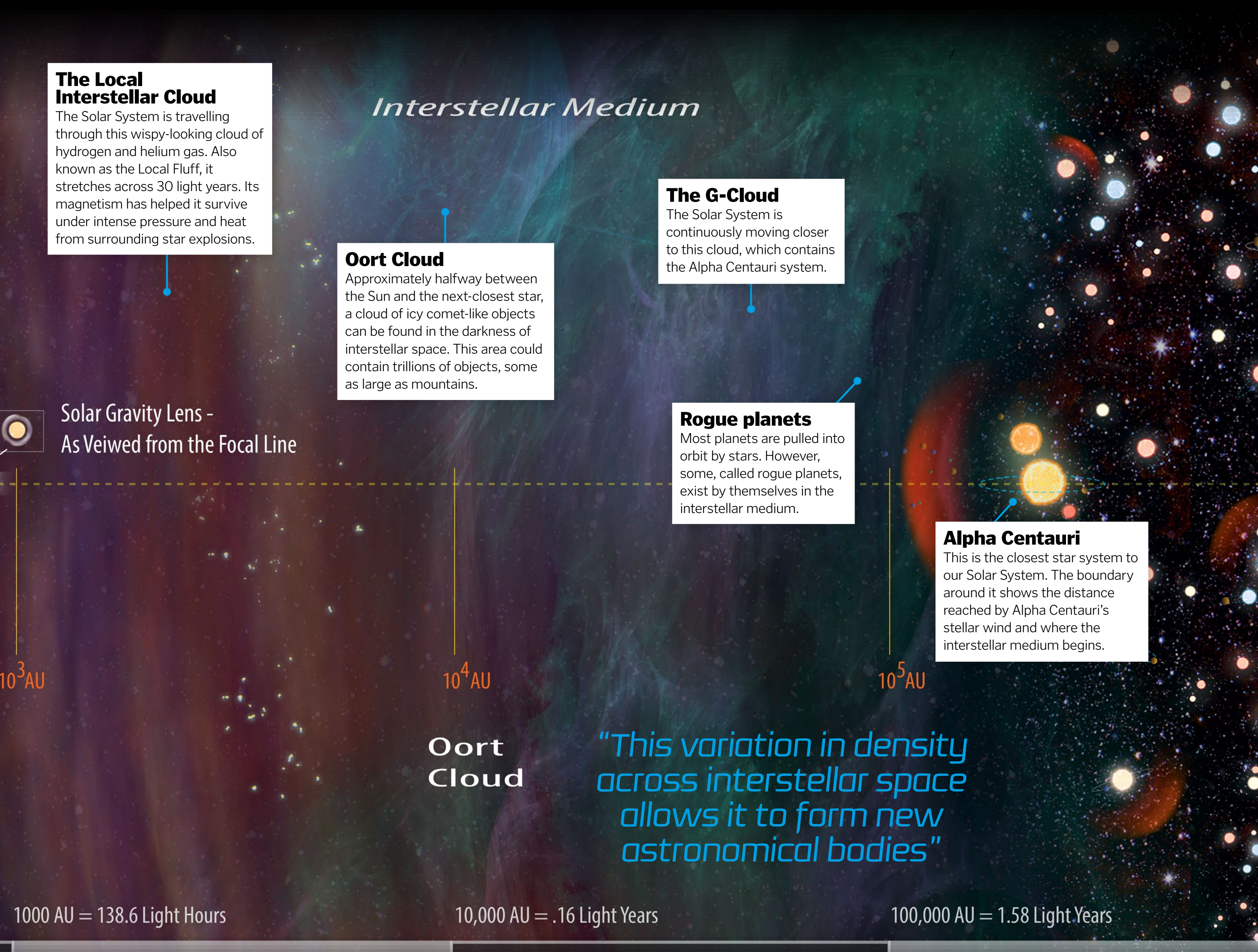
The environment between the galaxy's stars contains large clouds of gas – mainly made up of hydrogen and helium – and tiny dust particles. Its density can vary by location, but on average the medium contains just one atom per cubic centimetre. Mostly located at the outer arms of the Milky Way, where stars are more sparse, interstellar space makes up about five per cent of the galaxy's total mass.



When matter returns to the interstellar medium as a result of a star's death or being ejected into space from a star, it brings with it heavier elements such as iron and silicon. These elements are circulated by the gravity of surrounding stars, forming large, concentrated clouds that hold the potential to condense and form new stars. As this matter condenses, it forms molecular clouds – also known as stellar nurseries – where stars are born. It's this variation in density across interstellar space that allows it to form new astronomical bodies, like stars and the complex planetary systems we know today. We have the continuous evolution of the material between the stars to thank for our home world and our existence.



As Voyager 1 (top) entered interstellar space, Voyager 2 (bottom) was exploring the outer reaches of the solar bubble



> *"This variation in density across interstellar space allows it to form new astronomical bodies"*

Why do stars twinkle?

How Earth's atmosphere turns starlight on and off

© Getty

Sirius, also known as Alpha Canis Majoris, is the brightest star in the night sky

On a clear and cloudless night away from light pollution, you can see around 6,000 twinkling stars in the sky. The reason they twinkle is thanks to Earth's atmosphere acting like a humongous house of mirrors, scattering the light before it reaches the surface. Looking through telescopes on Earth, stars appear as tiny pinpoints of light that appear to flicker on and off. This is because a single beam of light entering the atmosphere is refracted across many different layers.

Hubble snapped this image of the Eta Carinae system, containing one of the brightest stars in the night sky, which is 7,500 light years away

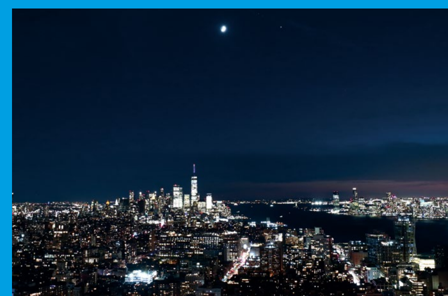
© NASA

Changing air density, winds and convection currents in atmospheric layers cause the travelling light to 'zig-zag' its way down to your eyes instead of moving in a straight line. This pattern of movement creates the 'twinkle', known as scintillation. The position of the star, depending on where you're standing, will also affect how much it twinkles. For example, when a star is directly overhead, the light has to travel through less atmosphere to reach your eye than if you were looking at a star near the horizon.

Although it's led to a charming nursery rhyme, scintillation is a problem when you want to observe a star more closely. Astronomers have reached into space to position telescopes, such as the Hubble Space Telescope, which observes past the interference of Earth's atmosphere to capture stars and constellations in all their glory.

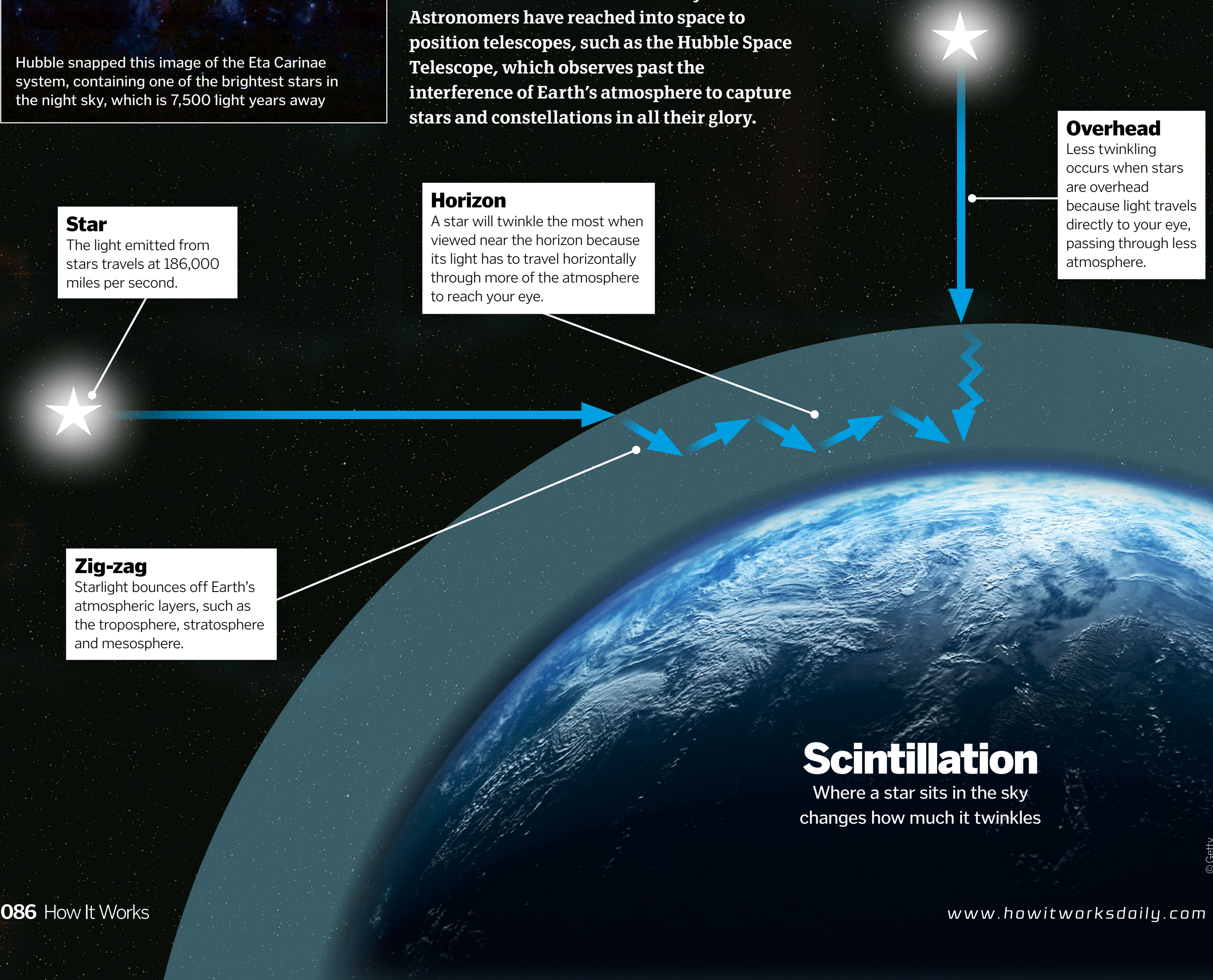
Why don't planets twinkle?

Planets appear consistent due to their proximity to Earth and how they reflect light. Stars are sources of light, emitting light in all directions, the same as a light bulb or a candle. Planets, on the other hand, are reflective discs in the sky with many observed points of light that traverse Earth's atmosphere. This means that if one beam of the planet's light is being 'zigged' one way by Earth's atmosphere, then another may be 'zagged' in the other direction, which results in there likely always being enough light reaching your eye without you noticing any scintillation.



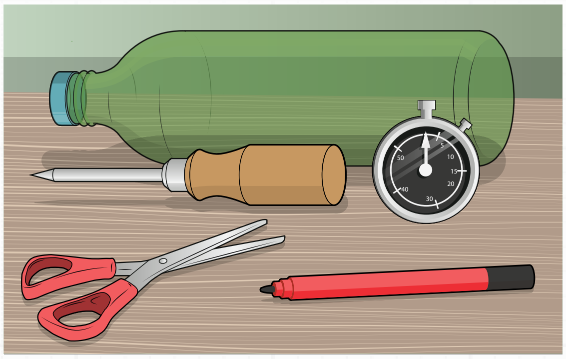
© Getty

The Moon, Saturn and Jupiter formed a triangle over New York City in November 2020



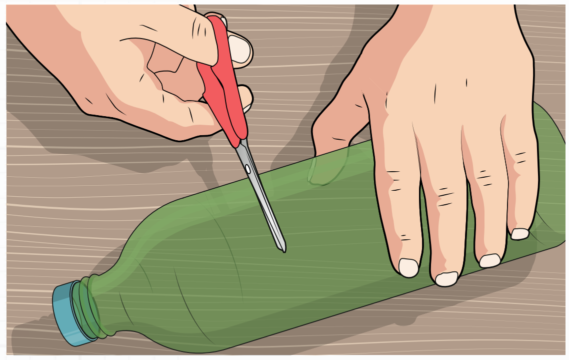
How to make a water clock

Measure the passing of time using this ancient method



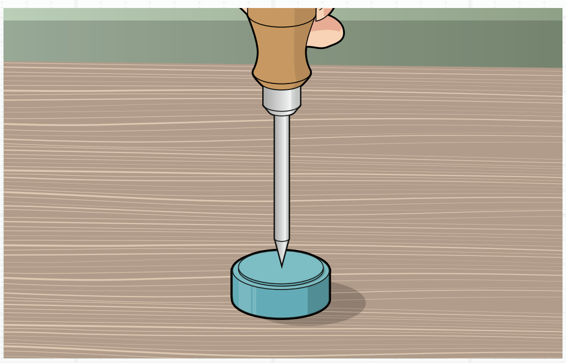
1 Gather your equipment

To make this simple clock you will need a plastic water bottle with a screw-on lid, scissors, a sharp tool and a permanent marker. You should also have a watch or clock to make accurate clock markings.



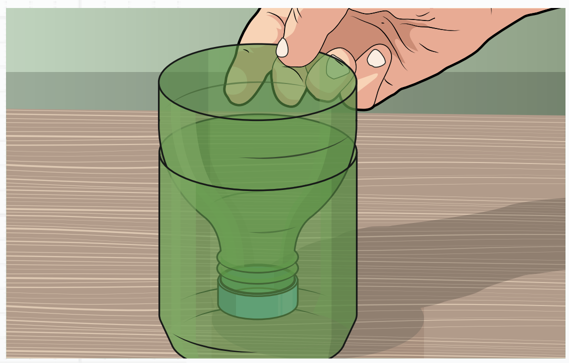
2 Cut the bottle

Using your pair of scissors, cut the plastic bottle in half. Check the lengths of the two pieces and try to make the top – the end with the opening – slightly shorter than the base.



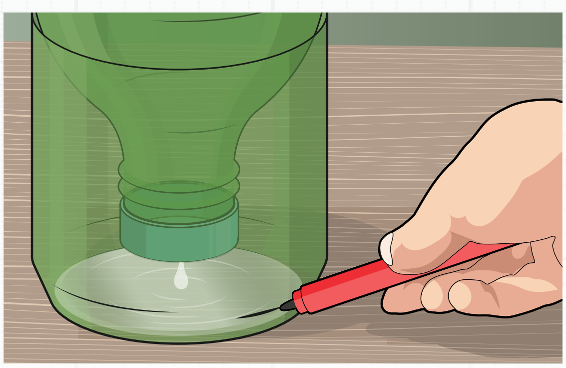
3 Pierce the bottle top

Find a tool with a sharp, pointed end and use this to create a small hole in the bottle's lid. Try not to make this hole any larger than three millimetres. When you have done this, screw the lid back onto the bottle.



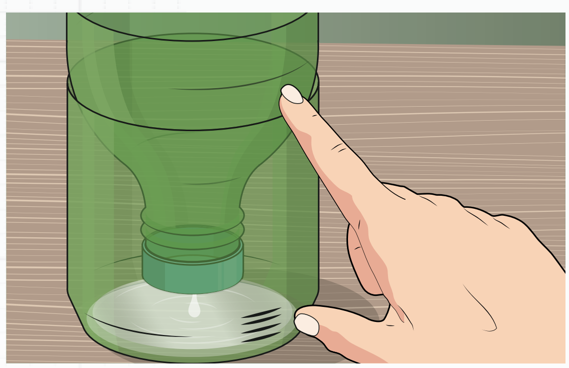
4 Connect the two halves

Turn the top half of the bottle upside down and insert it into the bottom half. Make sure that the bottle top doesn't touch the base and sits ten centimetres or more above it.



5 Mark your minutes

Fill the top of your water clock with water and check the time on your watch or clock. The water should continuously drip into the base. When one minute has passed, draw a line where the water level has reached. Repeat this every minute until the water stops.



6 Measuring time

With your minutes marked, your clock is ready to go. Now that you have plotted minute intervals, you can use your water clock to track time. By counting the number of lines the water has reached, you can use it as a timer for household activities.

SUMMARY

Before modern clocks were invented, ancient civilisations used water clocks to monitor changing water levels at a consistent pace. Called 'clepsydras', they gave people an indication of how much time they had spent carrying out activities. With your water clock, the hole in the lid is small enough to show visual differences between minutes, without using up the water too quickly. If you wish to track more time, you can experiment with larger containers. As the dripping water is a visual representation of time passing, the more water you use, the more time you can record.

NEXT ISSUE...
Make chalk from egg shells

BRAIN DUMP

Because enquiring minds need to know...

MEET THE EXPERTS

Who's answering your questions this month?

JO ELPHICK

ANDY EXTANCE

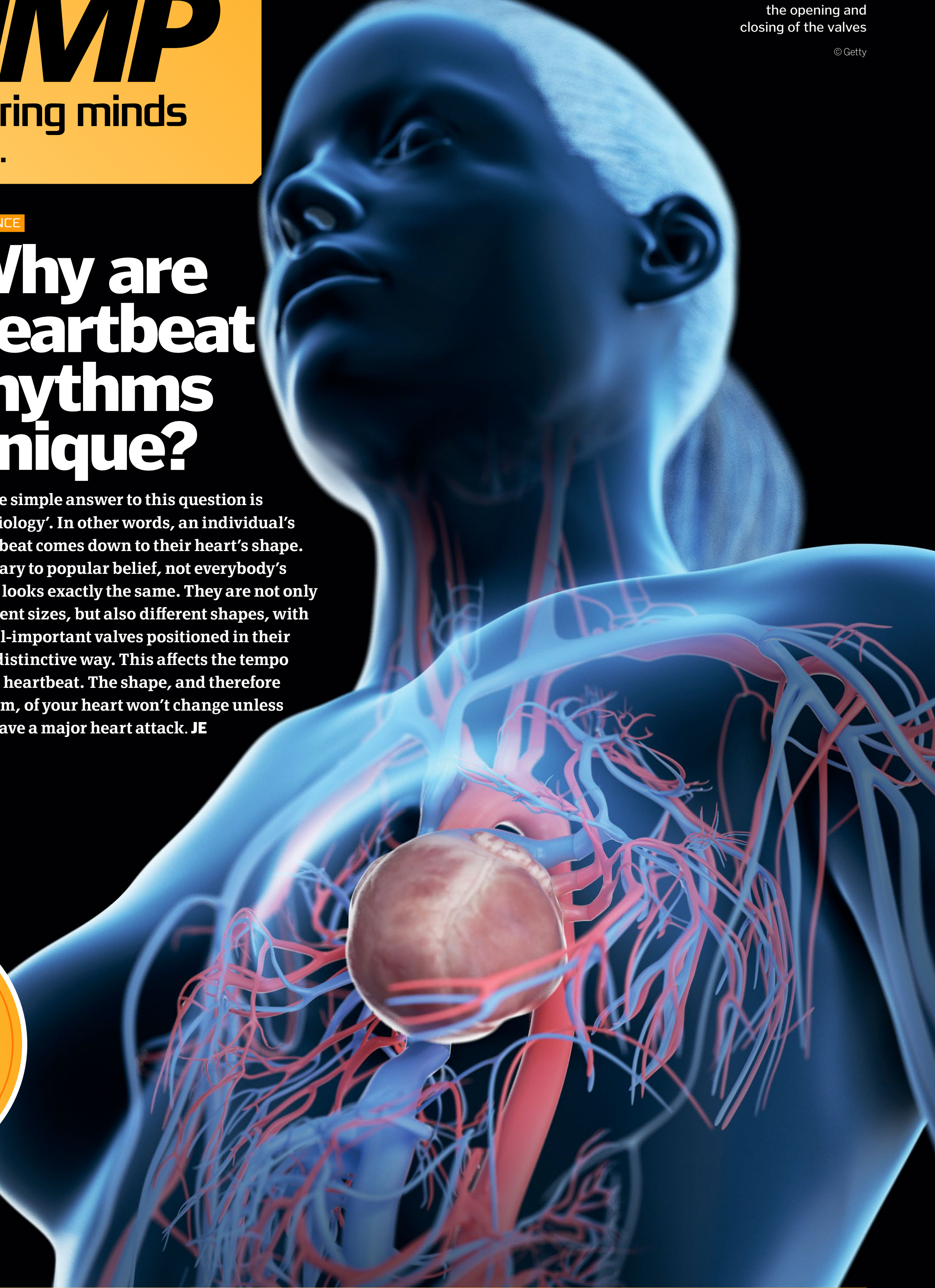
ANDREW MAY

AMY GRISDALE

SCIENCE

Why are heartbeat rhythms unique?

■ The simple answer to this question is 'physiology'. In other words, an individual's heartbeat comes down to their heart's shape. Contrary to popular belief, not everybody's heart looks exactly the same. They are not only different sizes, but also different shapes, with the all-important valves positioned in their own distinctive way. This affects the tempo of the heartbeat. The shape, and therefore rhythm, of your heart won't change unless you have a major heart attack. **JE**



The sound of your heartbeat is made by the opening and closing of the valves

© Getty

DID YOU KNOW?

Egyptians used charcoal to absorb smells in 1550 BCE

WANT ANSWERS? Send your questions to...

How It Works magazine | @HowItWorksmag | howitworks@futurenet.com

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ENVIRONMENT

If squirrels hibernate, why do I see them in Britain all year round?

James Lee

There are lots of different kinds of squirrels around the world that hibernate. Ground squirrels bed down for the winter, but tree squirrels don't. Both species that live in the UK are tree squirrels that stay active all year. The only British mammals that truly hibernate are hedgehogs, bats and dormice. **AG**

Thankfully these days our powerful electric showers heat up quickly

© Getty

TECHNOLOGY

How do electric showers work?

@maia_h3 (instagram)

Showers are a bit like kettles that you stand under, but much more powerful. They use insulating materials that do the opposite of what most electric gadgets want to do – they block electricity flowing through. As electricity struggles to get past, it releases heat; the part that does this is called a heating element. Normally this is in a small tank in your shower.

When you press the on button, the element quickly makes cold water flowing in very hot. To cool the water, showers can mix the hot water coming out with unheated cold water that comes in. **AM**

DID YOU KNOW?

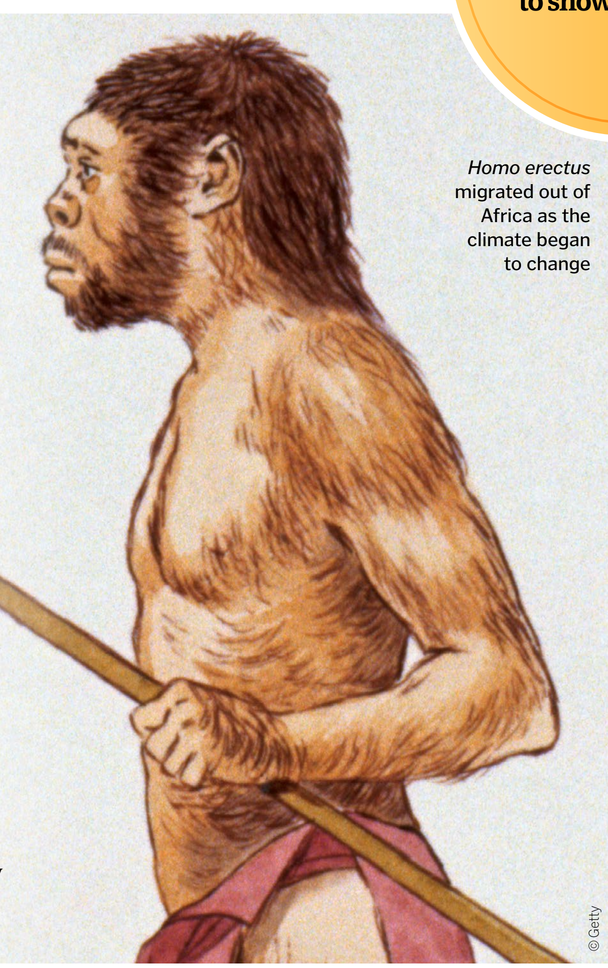
Cats bite their owners to show their love

HISTORY

When did humans first move out of Africa, and where did they go next?

Joshua Reader

Fossil records generally suggest that all hominins originated in Africa. It wasn't until *Homo erectus*, the longest surviving of all human species, that people began to move about the planet. *Homo erectus* first appeared in Africa about 2 million years ago, but quickly spread across Western Asia and then into Eastern Asia and Indonesia around 1.8 million years ago. It is thought that some left Africa via the Levantine corridor, a thin strip of land connecting Africa to Eurasia, while others followed the Horn of Africa. It is thought that early modern humans reached Europe around 210,000 years ago. **JE**



Homo erectus migrated out of Africa as the climate began to change

© Getty

© NASA

The Kuiper Belt object Arrokoth, as photographed at close range by New Horizons

SPACE

What is New Horizons doing now that it's done a flyby of Pluto?

Sonya Nixon

Pluto lies in a region of space known as the Kuiper Belt, which also contains a large number of smaller, asteroid-like objects. Since its Pluto flyby in 2015, New Horizons has been observing some of these objects through its long-range telescope, sending data on their surface properties and rotation rates back to Earth. In January 2019 it made a close pass of one such object, Arrokoth, coming within 2,200 miles of it. **AM**

BRAIN DUMP

House cats have been bred to act like kittens. In the wild, adult cats don't purr. It's a form of communication from kitten to mother

© Getty

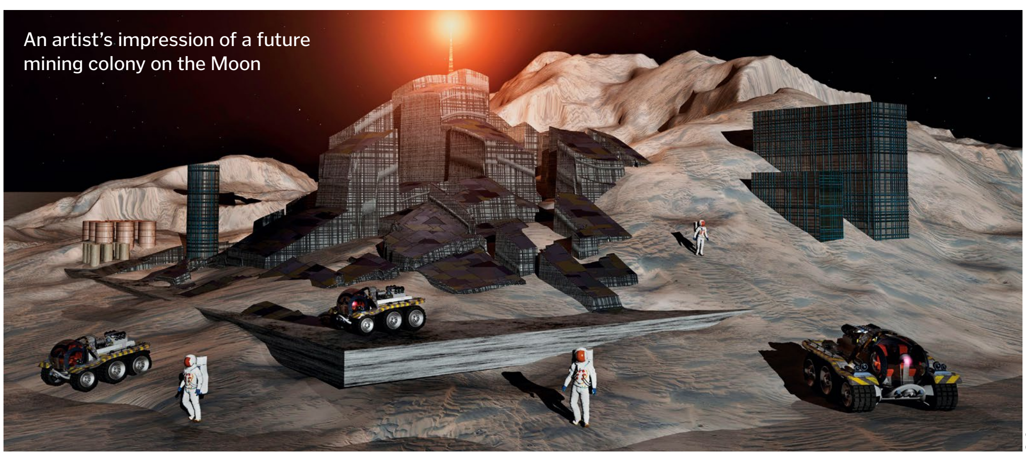
ENVIRONMENT

Are cats capable of loving their owners? Do they just show it in a different way to dogs?

Anna Counsell

Cats show their affection by spending time in their owner's company, playing and making physical contact. Their expression of love is different from a dog's because of the way the two species evolved.

Dogs and their wild ancestors found success working in packs and learned how to form strong bonds within these groups. Besides lions, almost all wild cats spend their lives alone. Two wild cats are more likely to fight than give each other a welcoming sniff. Pet cats are much friendlier than their wild counterparts thanks to over 4,000 years of domestication. **AG**



An artist's impression of a future mining colony on the Moon

© Getty

SPACE

Considering how far space exploration has come in 60 years, where will we be by the 2080s?

Rafael Schofield

During its first half a century, space exploration was the goal of NASA and other national space agencies, who approached it from a scientific perspective. This will continue, probably with a more intensive focus on searching for life elsewhere in the Solar System, which may well be found by robotic probes exploring the moons of Jupiter and Saturn. In parallel, the boom in commercially motivated space travel that we've seen in the last decade is likely to become increasingly dominant – for example, tourist trips to 'resorts' on the Moon and Mars, together with industrial activities such as mining on the Moon and asteroids. **AM**

© Getty

SCIENCE

Why are the tips of my hair lighter than at the root?

Joy Brooks

It's all down to how much Sun your hair gets. The ends of your hair have been around longer than the roots, and have had the melanin bleached out by the Sun. Melanin is the pigment that gives your hair its natural colour. **JE**

DID YOU KNOW?

Your heart beats 115,000 times per day

© Getty

SCIENCE

How does activated charcoal work?

@cathode149 (instagram)

Activated charcoal soaks up smells and cures poisoning because it has lots of tiny holes in it. That means it has lots of surfaces that poison or smell chemicals can land on. The electrons in both the carbon and the absorbed chemicals effectively become tiny magnets that stick together. **AE**

© Getty

TECHNOLOGY

How do sunglasses protect our eyes and how do polarised sunglasses work?

@louistyndall (instagram)

Sunglasses reduce how bright light seems because they are covered in coatings that block some of it getting through. More importantly, their coatings should block invisible but harmful ultraviolet (UV) rays. Light waves move just like a wave that forms in a rope as you shake it. Polarised sunglasses have a light-blocking pattern involving rows of tiny stripes, and only some waves can squeeze through. That stops glare from reflected light getting in your eyes. **AE**

© Getty

When almost 90 per cent of wild Tasmanian devils were wiped out, the species was saved by a breeding program to create 300 healthy animals

ENVIRONMENT

What's the minimum number of individuals needed to save a species from extinction, like the white rhino?

Wesley Wood

There is no magic number to guarantee a species is safe from extinction. The minimum viable population of a species depends on their reproductive behaviour and the environment. Even if there are thousands of animals within a population, an extreme weather event could still eliminate them all. Scientists estimate that a minimum of 50 prevents a species from having to inbreed and a population of 500 is large enough to survive drastic environmental change.

The northern white rhino is now functionally extinct. There are only two left on Earth, and they're both female. The southern white rhino population dipped below 50 in the 1990s, but thanks to massive conservation efforts it stands at around 17,000 today. **AG**

SPACE

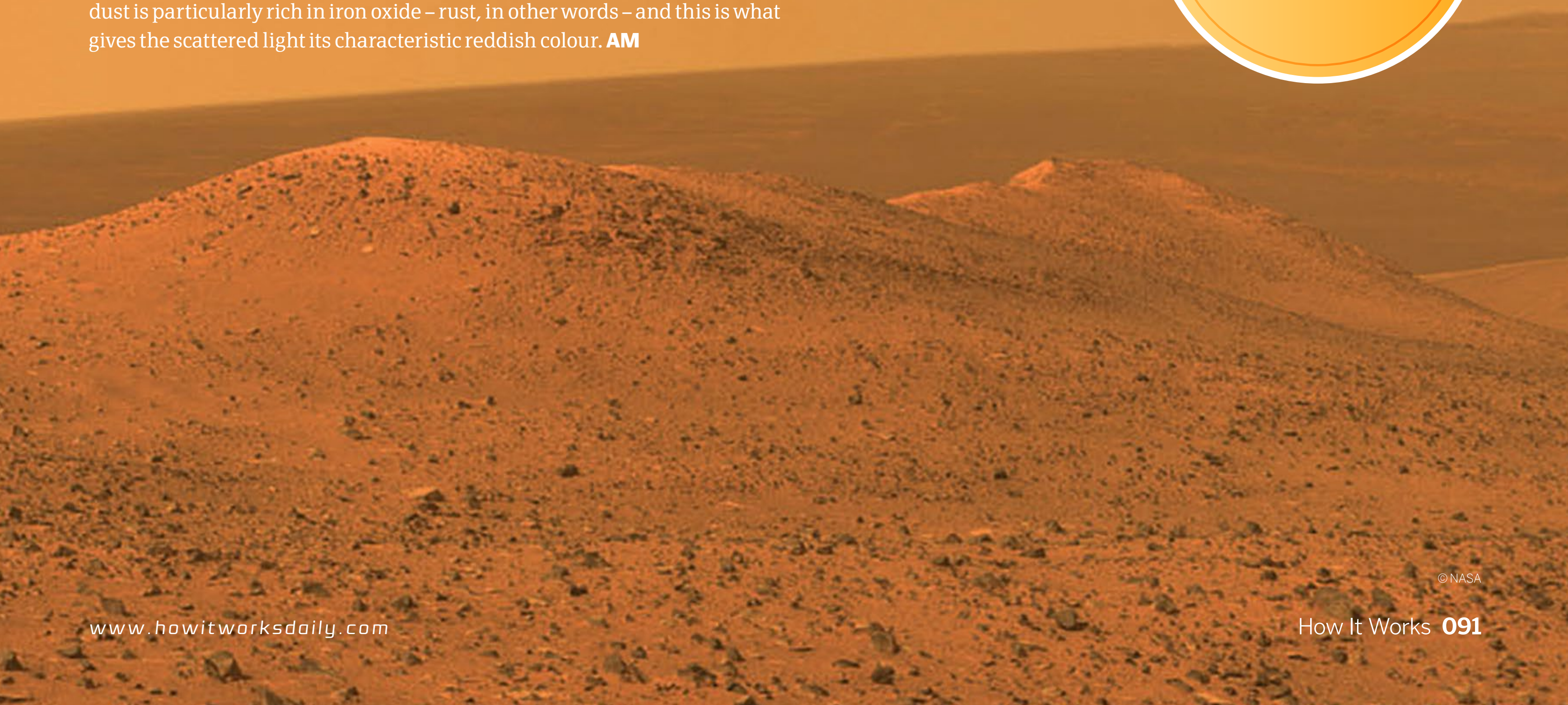
Why is the sky red on Mars?

Max Hall

Although the Martian atmosphere is very thin, it contains a relatively large proportion of dust, and this dust scatters sunlight as it passes through. The dust is particularly rich in iron oxide – rust, in other words – and this is what gives the scattered light its characteristic reddish colour. **AM**

DID YOU KNOW?

Arrokoth is the most distant object visited by a spacecraft



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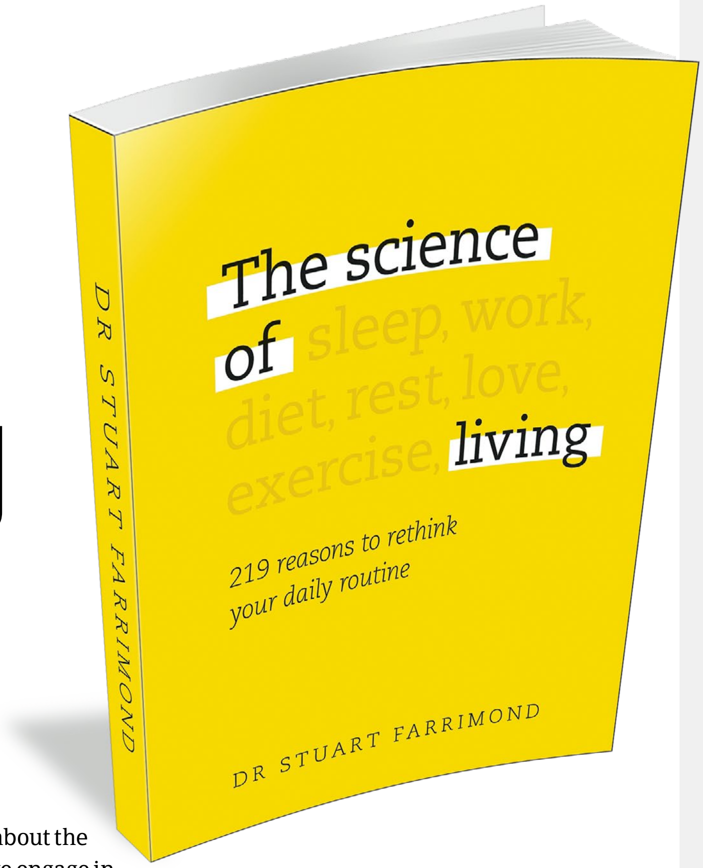
BOOK REVIEWS

The latest releases for curious minds



The Science of Living

HAVE YOU BEEN DOING LIFE WRONG?

- Author: **Dr Stuart Farrimond**
- Publisher: **DK**
- Price: **£17.99 / $25**
- Release: **Out now**

Most of us don't think twice about the little habits and routines we engage in between the bigger stuff. The hours of work we put in a day, managing our diet, an exercise regimen, hobbies and bedtime routine tend to throw shade on the small things. Did you ever consider, for example, whether you're drinking your morning coffee at the right time? Or whether you've got your central heating or air conditioning turned up too high? Medical doctor, teacher, presenter and author Dr Stuart Farrimond has thought about these things in an impressive level of scientific detail. After a frightening brush with cancer in 2008, he quit active medical practice and poured his energy into science communication, education and using science to live life better. If this book is the cumulative result of over a decade in this field, then he should be very proud of it.

The Science of Living: 219 Reasons to Rethink Your Daily Routine is split into four roughly even categories for morning, afternoon, evening and nighttime activities. Each page or double-page spread poses a question about one facet of the average, first-world person's daily routine: why do I have bad breath in the morning? Will digital devices keep me awake? Is there such a thing as a mid-life crisis? Like any good medical practitioner, Dr Stu isn't afraid to broach the awkward topics of your daily routine, so prepare to find out why you poo at the same time every morning! Simple graphics, charts and diagrams accompany each topic, and Dr Stu writes clearly and comprehensively, seeding the text with bite-sized facts and figures so even the most mundane-sounding of these questions have a fascinating answer.

Even if you're not looking to make any changes to your lifestyle, *The Science of Living* is a worthwhile read. It's the kind of book you can pick up and consume in single servings: you can spend just five minutes discovering the answer to a question you've had for years, but we guarantee that once you've read one, you can't help but turn the page to find out more.

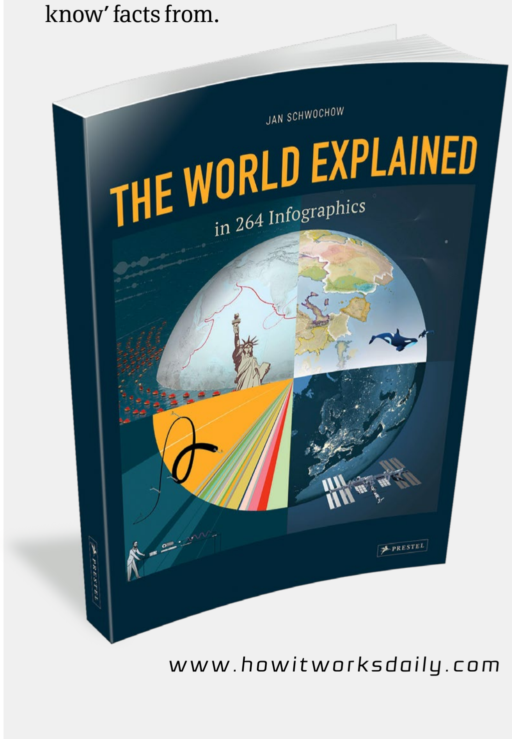
> *It's the kind of book you can pick up and consume in single servings*

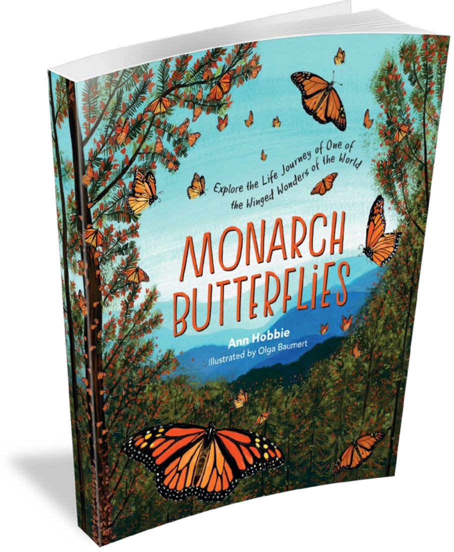
The World Explained in 264 Infographics

FOR FACTS, STATS AND FIGURE LOVERS

- Author: **Jan Schwochow**
- Publisher: **Prestel**
- Price: **£49.99 / $65**
- Release: **4 March**

From the flagships of 15th-century China to the Sun's inevitable consumption of our planet, this illustrated behemoth of a book presents practically everything there is to know about the Earth in satisfying stats and graphics. It's great for a visual learner, who will enjoy the illustrations of how the immune system works, the inside of the human heart or our particular favourite – the map of people's blood types by country. It showcases science in a systematic, easily understandable way, and that's the theme throughout: representing information about a wide range of topics in a fun and interesting way. It's not one for a sit down on a Sunday afternoon with a cuppa, but rather a great coffee-table book to draw 'did you know' facts from.





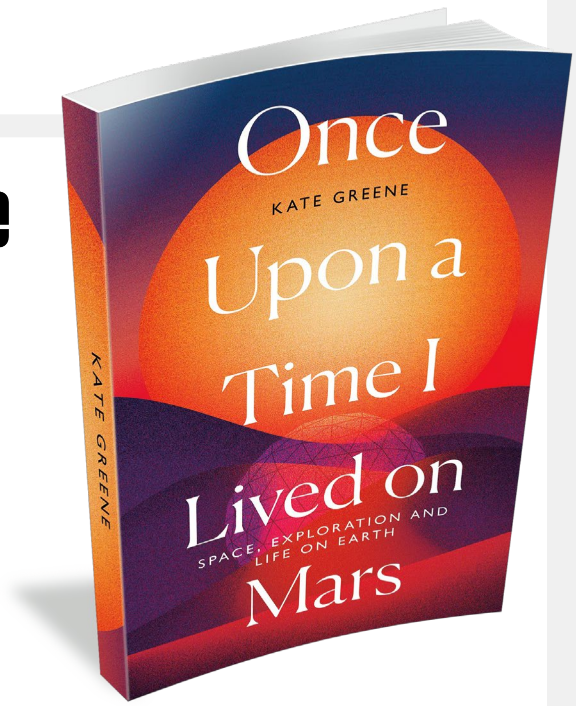
Monarch Butterflies

FOLLOW THE LIVES OF THESE FASCINATING FLYERS

- Author: **Ann Hobbie**
- Publisher: **Storey Publishing**
- Price: **£12.99 / $15.95**
- Release: **2 March**

The striking black-and-orange wings of monarch butterflies are instantly recognisable. But as they pass you by in a fleeting flutter, you are witness to a tiny fraction of their complex lives. With this book, children can explore every stage of these butterflies' journeys. Beginning with their dramatic double entrance into the world, both the science and anatomy of the hatching caterpillar, followed by their mighty winged reveal, are explained. The butterflies' famous flights south to central Mexico are depicted with vibrant imagery, intriguing facts and clear migration maps.

The immersive illustrations by Olga Baumert will keep children captivated by every page as they introduce a new significant event in these insects' lives. From their cultural importance, representing human souls at Mexico's 'Day of the Dead' festival, to the crucial issues surrounding humans' impact on their habitat, the scenes share wider knowledge beyond nature's life cycle. The perfect balance of absorbing artwork with the conversational yet educational narrative transports the reader through these creatures' elaborate journeys and allows you to understand the importance of protecting these delicate lives.



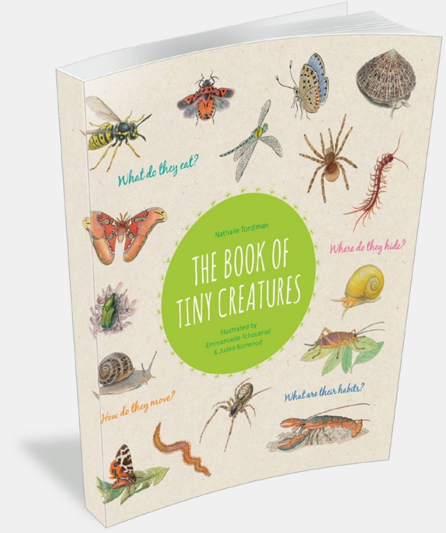
Once Upon a Time I Lived on Mars

SPACE, EXPLORATION AND LIFE ON EARTH

- Author: **Kate Greene**
- Publisher: **Icon Books**
- Price: **£14.99 / $27.99**
- Release: **Out now**

After Earth, Mars looks to be the most accessible planet for human settlement and exploration. You often hear of scientists' goals to reach the Red Planet, but what struggles will be faced when we eventually succeed? In 2013, science journalist Kate Greene was selected to take part in an analogue Mars mission called HI-SEAS. The simulation explored how four months in an isolated Martian environment would impact the volunteers. The real location? Inside a giant white dome on the Hawaiian volcano Mauna Loa.

Throughout this book, Greene provides her insight into this futuristic experience, while also detailing the extreme consideration, research and preparation that comes with a NASA mission. Her touchingly personal and informative account draws on human feelings and behaviours that we can all relate to. Why do we feel the need to constantly move forward and explore? How would our settled lifestyles on Earth affect us psychologically on a new planet? Admittedly not everyone would respond to the experience in the same way, but as someone who has tasted this possible future, Greene allows you to share in her experiences, struggles and awe. Faced with new technology, daily chores, a limited social life and an alien physical environment, these are just some of the realities of a life on Mars.



The Book of Tiny Creatures

DISCOVER THE LIFE IN YOUR BACK GARDEN

- Author: **Nathalie Tordjman**
- Publisher: **Princeton Architectural Press**
- Price: **£13.99 / $18.95**
- Release: **18 March**

If you've got an inquisitive young one at home, this guide to tiny ecology is a wonderful way to introduce them to the insects and molluscs that live either in your back garden, in the woods or down on the shoreline. This compact children's book is filled with snippets of information that answer questions like where do tiny creatures go in winter? And which insects have soft bodies? It also has activities spread throughout, like how to build a snail terrarium and how to catch tiny creatures. Its illustrations are not only beautifully drawn, but wonderfully detailed, helping to differentiate between species. During a time when we might be grasping to find activities to do at home, this book is an excellent way to explore the wildlife in your garden with the whole family.

This book is filled with snippets of information

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 Approximately how many human beings have ever lived?

- 7 billion
- 56 billion
- 107 billion
- 321 billion

Q2 What is a sea cucumber?

- A marine animal
- A type of coral
- An edible seaweed
- A type of rock

Q3 What's the coldest core temperature a human has survived?

- 1.2 degrees Celsius
- 8.2 degrees Celsius
- 13.2 degrees Celsius
- 22.2 degrees Celsius

Q4 What's the half-life of Plutonium-244?

- 120 seconds
- 45.2 days
- 24,100 years
- 81 million years

Q5 How fast was Curiosity travelling when it reached the Martian atmosphere?

- 32 miles per hour
- 3,200 miles per hour
- 8,200 miles per hour
- 13,200 miles per hour

Q6 What type of star is the Sun?

- G-type (yellow dwarf)
- K-type (orange dwarf)
- O-type (blue giant)
- F-type (white giant)

Spot the difference

See if you can find all six changes between the images below

Sudoku

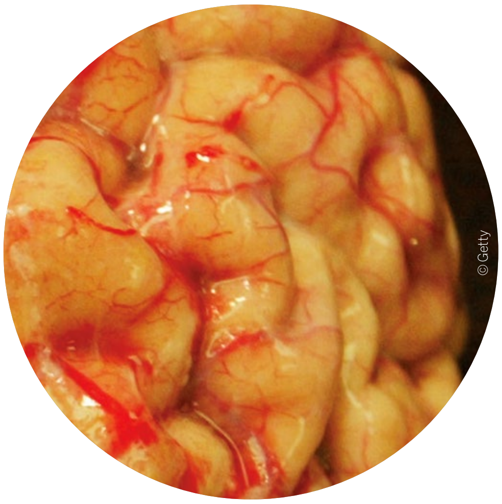
Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

4				6	9	3	5	
	6	3		2	5			
9			3			7	6	1
6	3					2		5
1	7							
5	4			3		1	9	
8		6			3	5	2	
	5	7	4		1	9	3	
3			2	5			1	

DIFFICULT

					1			4
			8	3				2
	9	7			2			
3		2	1					5
					3			
					7	4	3	
2				5	6			
7		4					5	3
	5				9		7	



What is it?

Hint: Have a think on this…

A ....

D	E	S	C	E	N	T	E	A	L	J	O	S	P	A
M	A	C	S	T	E	L	E	T	N	A	D	E	B	T
N	P	O	E	W	C	K	I	O	X	C	E	A	L	B
R	A	B	V	X	I	O	A	X	T	O	X	L	E	I
C	O	M	I	X	T	W	N	I	K	N	R	I	C	L
S	T	A	T	I	O	R	A	C	N	C	K	E	T	L
K	C	I	C	B	A	D	E	N	I	O	S	A	E	I
J	A	G	A	M	M	A	L	M	E	R	Y	O	W	O
F	K	R	O	R	D	E	V	R	E	D	N	O	I	N
R	C	A	I	E	X	T	R	A	P	E	O	L	D	S
V	I	J	D	E	W	S	T	W	I	M	B	L	E	Y
E	R	I	A	H	G	T	E	R	A	L	L	E	T	S
S	B	E	R	A	D	I	G	A	N	N	F	H	I	N
G	A	P	E	E	X	E	L	K	N	I	W	T	G	H
Q	U	E	T	N	A	P	O	L	E	O	N	B	O	B

Wordsearch

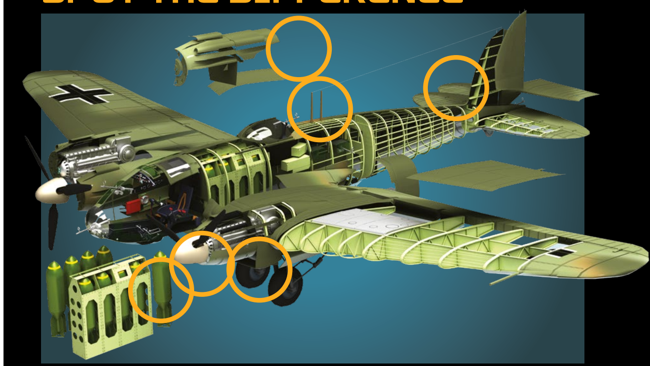
FIND THE FOLLOWING WORDS…

RADIOACTIVE
GAMMA
NAPOLEON
CONCORDE
STELLAR
SEA
DESCENT
EXTREME
BRICK
TOXIC
BILLIONS
TWINKLE

Check your answers

Find the solutions to last issue's puzzle pages

SPOT THE DIFFERENCE



QUICKFIRE QUESTIONS

Q1 99 per cent
Q2 All of the above
Q3 122 metres
Q4 70 per cent
Q5 Ironclads
Q6 A supercomputer

WHAT IS IT? …A CHICKEN

INBOX

Speak your mind...

© Naomi Cearns

11-year-old reader Henry has a passion for science

Rarest element

Dear **HIW,**

My son Henry (11) loves science and is just learning about the periodic table. He'd like to know all about the rarest element – what is it, what does it do and where can it be found?

Naomi and Henry Cearns

Thanks for your question and for sending in these great photographs. The elements on the periodic table make up everything that surrounds us, and as you've mentioned, some in higher volumes than others. On Earth the rarest of these elements to occur in nature is astatine. It's found in the planet's crust and is highly radioactive, with a half-life of just over 8.1 hours. At any one time, there is believed to be only one gram of this element in the Earth's crust. Scientists have also made synthetic elements in the laboratory that are even rarer and more unstable, including oganesson. Only five atoms of this element have ever been made, with a half-life of a fraction of a second.

Get in touch

If you have any questions or comments for us, send them to:

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WIN! A HAYNES MANUAL

From cars and skyscrapers to galaxies and even the Millennium Falcon, Haynes Manuals take all sorts of things apart, show the reader exactly how they work and how to repair and maintain them.

© Haynes

Letter of the month

Python pets

Hi **HIW,**

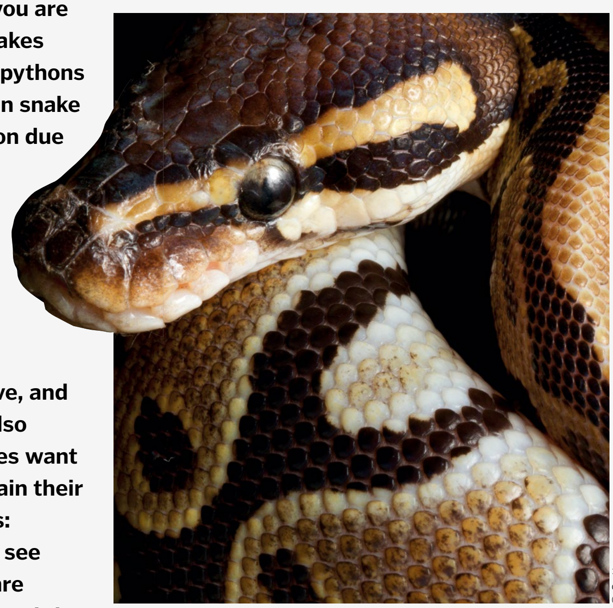
I've been reading **How It Works** magazine for seven months and it's so amazing. I love the sections about reptiles, like why is a snake's tongue forked. I am a reptile lover and I especially think that ball pythons are the cutest and the most beautiful creatures on Earth. I really want a ball python, but unfortunately most of my family don't think so. Do you have any ideas about how I can persuade them to love ball pythons and let me have one please? Thank you very much!

Ruoxin Li

Hi Ruoxin. We love how passionate you are about reptiles, but unfortunately snakes aren't everyone's favourite pet. Ball pythons are actually one of the most common snake species to keep as a home companion due to their handleability, docile nature and relatively easy maintenance. Although you can't force your family to buy one, making sure they know all the facts and don't follow some of the misconceptions about snakes is a good start.

These snakes are pretty impressive, and we can see why you want one. It's also important to know what these snakes want and need before buying one. They gain their name from their response to threats: curling into a tight ball shape. If you see your pet doing this, you know they are uncomfortable. You need to make sure it is kept in temperatures of at least 27 degrees Celsius and check with veterinary experts before buying so you know how to keep your python happy. Getting all the facts will help your family to be fully informed when they make their final decision.

A good idea might be to take a trip to your closest reptile centre when you can. While there, you and your family can learn from the experts, ask any questions and maybe even get to hold one. This can help your family get to know the animal better. Good luck with convincing your family.



© Getty

Ball pythons are also known as royal pythons

Snowy circles

Holly discovered the snow on her patio was melting to form a series of rings

© Holly Smith

Dear **HIW,**

Please can you tell me why the snow on the patio has melted in these strange circles? Thank you!

Best wishes

Holly Smith

Thanks for sending in this interesting photograph, capturing the pattern before it completely melted. Snow responds in different ways on various surfaces. In this case, the tile placement over the ground may have affected heat conductivity. The patio tiles add another layer to the ground in small patches, with regular gaps surrounding each.

These rings of snow seem to follow the tiles' patten, being found at the centre of each. Concrete is a much better conductor of heat than grass and other surfaces, and it is likely that the centre of the tiles is a slightly higher temperature than the concrete near the aerated gaps. This has led to the snow at the centre melting first, leaving holes.

Planetary puzzle

Generally, stars are bigger and brighter than planets

■ Dear **HIW,**

Is there a possibility of a star transforming into a planet or a planet to a star?

Laila Jones

Stars and planets generally don't change from one into the other, but there is an exception. Stars are hot, bright objects that generate their own energy. A planet doesn't radiate its own energy, but reflects it from the parent star it orbits. A star can technically become a planet if it's a brown dwarf. Brown dwarfs look like planets but are called 'stars' because they form in the same way other stars do. But they don't have enough mass to fuse hydrogen at their cores, which some scientists insist is the defining characteristic of a star. Instead they carry out the nuclear fusion of heavy hydrogen. They begin life glowing like other stars, eventually running out of fuel and cooling and becoming planet-like.

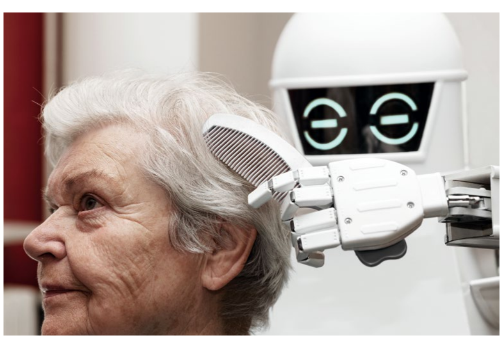
Robot takeover

■ Dear **HIW,**

Will we have robots for everything one day? We could even have support worker and carer robots.

Matthew Garner

People are constantly working to improve the efficiency and human qualities of computers so that they can carry out roles that we currently rely on humans for. Robot carers could be of great assistance in the future for our ageing population, but at the moment robots are mainly programmed to carry out a single function effectively. To be cared for by robots in the foreseeable future, you might need a whole family of them with their own specific duties. There are already robots being introduced to care homes to take on certain tasks, like combating loneliness, but being able to fully depend on a mechanical being will remain in fiction only for some time yet.



Some robots are designed to look like humans, but their lack of emotion makes 'carer robots' difficult

What's happening on... social media?

This month on Instagram we asked you: If you were a billionaire, what would you buy for your dream home?

@danielj868
A room that can be used for giant chess

@louistyndall
A huge fish tank filled with exotic marine life

@cathode149
Too many house plants

@y.f.lin_1214
A 50-metre swimming pool

@jack_macneilly
Mega garage

@scimaxfacts
A fully functional water park, spa and sauna!

@_ross_1468
A flight sim

NEXT ISSUE...

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FAST FACTS

Amazing trivia to blow your mind

15cm

THE EIFFEL TOWER IS A LITTLE BIT TALLER IN THE SUMMER

400,000

IN 2007, SMOG IN CHINA WAS CAUSING THOUSANDS OF PEOPLE TO DIE A YEAR

62 MILES

RADIO WAVES HAVE THE LONGEST WAVELENGTH IN THE EM SPECTRUM

9,000 METRES

BUMBLEBEES CAN FLY HIGHER THAN MOUNT EVEREST

ONE HOUR

IF YOU COULD DRIVE A CAR STRAIGHT UP, IT WOULDN'T TAKE LONG TO GET TO SPACE

THE SIACHEN GLACIER IN THE HIMALAYAS IS THE COLDEST, HIGHEST BATTLEFIELD IN THE WORLD

SQUIRRELS CHEWING THROUGH CABLES ARE THE CAUSE OF MOST POWER CUTS IN THE US

162,719 PINTS

THE AMOUNT OF GUINNESS THAT'S LOST IN FACIAL HAIR EVERY YEAR

1897

THE YEAR CANDY FLOSS WAS INVENTED BY DENTIST WILLIAM MORRISON

£1

BILLIONAIRE RICHARD BRANSON OFFERED TO BUY CONCORDE FOR A TINY SUM

THE CHILDREN OF IDENTICAL TWINS ARE GENETIC SIBLINGS, NOT COUSINS


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